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Understanding food technology evaluation across supply chain actors

A methodological and empirical analysis

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Abstract

World development trends such as increasing world population, climate change, urbanization, malnutrition, food waste and losses as well as resource scarcity are challenging the global food system. To address these challenges, there is a need for new food technologies at different levels of the food supply chain to ensure food safety and food security. New food technologies are key contributors in the transformation of food systems but they are dependent on the evaluation of the involved actors in the food chain (e.g. farmers, processors, traders, consumers). In this research, 'evaluation' is an umbrella term used to encompass the measurement of acceptance, adoption, intention, perception, and 'willingness to pay'. To investigate the research landscape of new food technology evaluation by involved chain actors in more detail, this thesis provides a systematic overview of theoretical models and factors. Furthermore, this thesis empirically applies various theoretical models in the domain of new food technology evaluation while focusing on different supply chain levels.

By means of a systematic literature review (*N*=183 studies), this thesis examined the overall research landscape of theory-based new food technology evaluation. Several research gaps were found, including a lack of evaluation research targeting chain actors other than consumers (e.g. farmers and processors). There was also a lack of research focusing on non-GM food technologies (e.g. upcoming new food technologies like CRISPR/Cas and 3D food printers) and food technologies in developing countries. The most often applied theories at consumer level were the Theory of Planned Behavior and Protection Motivation Theory. However, most studies developed their own models which included factors such as trust in institutions, information assessment, perceived risks and benefits, attitudes toward the product/technology, quality perception of the product, perceived behavioral control, and impact on health. These identified factors served as the basis to propose a new model for consumer studies: the so-called new Food Technology Acceptance Model. This model was empirically tested within this thesis.

From an empirical perspective, this thesis addresses identified research gaps while providing insights into new food technology evaluation research from both the demand side (i.e. consumers') and the supply side (i.e. traders') for different technologies (i.e. 3D-printed food, dietary supplements and improved packaging). Hence, well-known theories were tested for their applicability in the area of new food technology evaluation with respect to different technologies and supply chain levels.

A major finding of this research was based on a survey of 350 German consumers. This research found that the purchase decision involvement in health enhancing food technologies such as dietary supplements was highly influenced by individuals' health motivation rather

than their actual health statuses. Involvement, in turn, was an important predictor for the actual purchase of new food technologies. Furthermore, a survey of 463 German consumers suggested that people's intention to consume 3D-printed foods was largely influenced by the opinions of others (subjective norms); but, also on trust in institutions. Resulting from a survey with 80 Tanzanian traders, subjective norms were important predictors for traders' adoption of an improved packaging; however, perceived behavioral controls by traders had a larger effect.

The contribution of this thesis is thus multi-fold. First, this thesis contributes to the theoretical understanding of technology evaluation by (1) extending the focus beyond consumers to other food supply chain actors, (2) targeting a wider range of new food technologies, (3) examining the use of well-established explanatory models, (4) identifying key factors, and (5) developing a theoretical model including main factors influencing new food technology evaluation at consumer level. Furthermore, this thesis uses different data collection and data analysis methods, and thus, adds to the methodological understanding of conducting research within this domain. Through applying theoretical concepts, this thesis extends the assessment of food technology evaluation on consumer and trader levels, and thus contributes empirical insights into the discussion of new food technology implementation throughout the supply chain. Eventually, this thesis concludes with recommendations for future research. Recommendations include, for example, to focus more on all relevant actors within the food technology evaluation research for a more holistic understanding of the implementation process of new food technologies along the supply chain. This would enhance the success of these technologies to have a fruitful impact to tackle the challenges in the food system.

Zusammenfassung

Weltweite Entwicklungstrends wie zunehmende Weltbevölkerung, Klimawandel, Urbanisierung, Mangelernährung, Verschwendung und Verlust von Nahrungsmitteln sowie Ressourcen-knappheit fordern das globale Nahrungsmittelsystem heraus. Um diese Herausforderungen anzugehen und damit Lebensmittel- und Ernährungssicherheit zu gewährleisten, bedarf es neuer Lebensmitteltechnologien auf verschiedenen Ebenen der Lebensmittelversorgungskette. Neue Lebensmitteltechnologien sind wesentliche Schlüssel-faktoren in der Umgestaltung des Ernährungssystems. Sie sind allerdings abhängig von der Evaluation der involvierten Akteure entlang der Wertschöpfungskette (u.a. Landwirte, Verarbeiter, Händler, Konsumenten). In dieser Arbeit umfasst der Überbegriff ‚Evaluation' die Messung von Akzeptanz, Adoption, Intention, Wahrnehmung und Zahlungsbereitschaft. Um die Forschungslandschaft der Evaluation neuer Lebensmitteltechnologie durch involvierte Lebensmittelwertschöpfungs-kettenakteure genauer zu untersuchen, bietet diese Arbeit einen systematischen Überblick von theoretischen Modellen und Faktoren. Darüber hinaus wendet diese Arbeit empirisch verschiedene theoretische Modelle im Bereich der Evaluation neuer Lebensmitteltechnologie an, wobei der Fokus auf verschiedenen Ebenen der Lieferkette liegt.

Durch eine systematische Literaturrecherche (N=183 Studien) wird in dieser Dissertation die umfassende Forschungslandschaft der theoretisch basierten Evaluierungsforschung neuer Lebensmitteltechnologie dargestellt. Mehrere Forschungslücken wurden dabei aufgezeigt, einschließlich der nicht vorhandenen Evaluierungsforschung, die andere Akteure als Verbraucher (wie Landwirte und Verarbeiter) betrachtet. Außerdem fehlt in der Forschung der Fokus auf nicht gentechnisch veränderte Lebensmitteltechnologien (z.B. aufkommende neue Lebensmitteltechnologien wie die Nutzung von Lebensmittelabfällen, CRISPR/Cas und 3D-Lebensmitteldrucker), als auch Evaluationsforschung neuer Lebensmitteltechnologien in Entwicklungsländern. Die am häufigsten angewandten etablierten Theorien auf Verbraucher-ebene waren die Theorie des geplanten Verhaltens und die Schutzmotivationstheorie. Die meisten Studien entwickelten jedoch ein eigenes Modell, das hauptsächlich auf den Faktoren Vertrauen in Institutionen, Zugang zu Informationen, wahrgenommenen Risiken und Nutzen, Einstellungen zu Produkt/Technologie, Qualitätswahrnehmung des Produkts, wahrgenommener Verhaltenskontrolle und Auswirkungen auf die Gesundheit basierte. Diese identifizierten Faktoren dienten als Grundlage, um ein neues Modell für Verbraucherstudien zu entwickeln. Dieses sogenannte Akzeptanzmodell für Lebensmitteltechnologie wird im Rahmen dieser Arbeit empirisch getestet.

Aus empirischer Perspektive werden in dieser Dissertation einige identifizierte Forschungs-lücken angesprochen. Dabei werden Einblicke in die Evaluationsforschung neuer Lebensmittel-technologien durch Verbraucher sowie von Akteuren der Angebotsseite

(vertreten durch Händler) am Beispiel verschiedener Technologien (3D-gedruckte Lebensmittel, Nahrungs-ergänzungsmittel und verbesserte Verpackungen) gegeben. Für diese Analysen werden bekannte Theorien auf ihre Anwendbarkeit im Bereich der Evaluierung neuer Lebensmitteltechnologie in Bezug auf verschiedene Technologien und Wertschöpfungsketten-ebenen getestet.

Ein wesentliches Ergebnis dieser Arbeit basiert auf einer Umfrage mit 350 deutschen Verbrauchern. Diese Umfrage fand heraus, dass die Involvierung in Kaufentscheidungen bei gesundheitsfördernden Lebensmitteltechnologien wie Nahrungsergänzungsmitteln eher durch die gesundheitliche Motivation des Einzelnen, als durch den tatsächlichen Gesundheitszustand beeinflusst wurde. Die Involvierung war wiederum ein wichtiger Indikator für den Kauf neuer Lebensmitteltechnologien. Eine Online-Umfrage mit 463 deutschen Verbrauchern hat gezeigt, dass die Absicht der Verbraucher, 3D-gedruckte Lebensmittel zu konsumieren, hauptsächlich von der Meinung anderer (subjektive Norm), aber auch vom Vertrauen in Institutionen beeinflusst wurde. Eine Umfrage mit 80 tansanischen Händlern ergab, dass subjektive Normen wichtige Indikatoren für die Akzeptanz einer verbesserten Verpackung waren. Die wahrgenommenen Verhaltenskontrollen von Händlern hatten jedoch einen größeren Effekt.

Der Beitrag dieser Arbeit ist vielfältig. Erstens trägt diese Arbeit zum theoretischen Verständnis der Technologiebewertung bei, indem (1) der Fokus über die Verbraucher hinaus auf andere Akteure der Lebensmittelversorgungskette ausgedehnt wird, (2) ein breiteres Spektrum neuer Lebensmitteltechnologien angesprochen wird, (3) etablierte theoretische Erklärungsmodelle untersucht werden, (4) Schlüsselfaktoren ermittelt werden und (5) ein neues theoretisches Modell mit Hauptfaktoren, die die Bewertung der neuen Lebensmitteltechnologie auf Verbraucherebene beeinflussen, entwickelt wird. Darüber hinaus verwendet diese Arbeit verschiedene Methoden der Datenerfassung und Datenanalyse und trägt somit zum methodischen Verständnis der Forschung in diesem Fachgebiet bei. Durch die Anwendung theoretischer Konzepte erweitert die Dissertation das Assessment der Evaluierung von Lebensmitteltechnologie auf Verbraucher- und Händlerebene und trägt so zu empirischen Einsichten in die Diskussion über die Implementierung neuer Lebensmitteltechnologie entlang der Lieferkette bei. Die Arbeit schließt mit Empfehlungen für zukünftige Forschung ab. Zu den Empfehlungen gehört beispielsweise die stärkere Fokussierung auf alle relevanten Akteure in der Evaluationsforschung, um ein ganzheitlicheres Verständnis des Umsetzungsprozesses neuer Lebensmitteltechnologien entlang der Wertschöpfungskette zu erhalten. Dies würde den Erfolg dieser Technologien verbessern, um die Herausforderungen im Lebensmittelsystem erfolgreich anzugehen.

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List of Abbreviations

CB-SEM	Covariance based Structural Equation Modeling
EC	European Commission
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FTAM	Food Technology Acceptance Model
GM	Genetically modification
HBM	Health Belief Model
HPP	High Pressure Processing
PEF	Pulsed Electric Field
PLS-MGA	Partial Least Squares Multi Group Analysis
PLS-SEM	Partial Least Squares Structural Equation Modeling
PMT	Protection Motivation Theory
RQ	Research Question
SDG	Sustainable Development Goals
TAM	Technology Acceptance Model
TPB	Theory of Planned Behavior
TRA	Theory of Reasoned Action
UN	United Nations
US	United States
WHO	World Health Organization

Part I: Introduction

1 Introduction

1.1 Challenges to establish new food technologies in the food system

Throughout the centuries, many technologies impacted food and agriculture to make the human diet more varied, palatable, and safer whereas changes became more rapid with the beginning of the industrialization (Lusk et al., 2014). According to the Regulation (EC) No 258/97 from 1997, novel foods are defined as foods or food ingredients to which a production process that is not currently used has been applied. This new process gives “rise to significant changes in the composition or structure of the foods or food ingredients which affect their nutritional value, metabolism or level of undesirable substances” (European Commission, 1997 Article 1). Thus, novel food technologies are operations to produce novel food and have become a key factor in the transformation of food systems (FAO, 2017). The global food system demands new food technologies to tackle challenges like increasing world population, climate change, urbanization, malnutrition, and resource scarcity. However, humans are evolutionary very skeptical toward new foods (Lusk et al., 2014) which highly constraints the success of novel food technologies. Thus, it is of high research interest to understand how individuals evaluate new food technologies and what determines their perceptions.

According to Figure 1.1, this thesis motivates its research focus by first addressing trends and challenges in the food system in order to shed light on the drivers of the development of new food technologies in the 21th century (section 1.1.1). After presenting the latest food technologies that promise to tackle the challenges in the food system (section 1.1.2), arguments for the necessity to focus on the evaluation of new food technologies by individual chain actors are exhibited (section 1.1.3).

1.1.1 World development trends and challenges in food production

Our world in the future will be shaped by geopolitical, environmental, economic, social and technological shifts (Augustin et al., 2016). The current world population is expected to be close to 10 billion in 2050 (UN-DESA, 2015), and thus, the demand for food is projected to increase (Godfray et al., 2010). In addition, the world population is growing older with rising chronic diseases, while ageing is now also accelerating in low-income countries (Augustin et al., 2016; FAO, 2017; Weaver et al., 2014). This trend results in the need to offer sufficient supply of healthy food products and to adopt appropriate healthy diets. More people now live in cities than in rural areas. The life in cities is accompanied by a massive shift in food preferences toward meat and dairy products as well as heavily-processed foods (FAO, 2017; Willett et al., 2019) as part of a general broad dietary transition. Further, urbanization and the emergence of megacities requires easy storage and transportation of food (FAO, 2017). Inefficient resource use is highlighted by the fact that globally around one-third of all food

produced is lost or wasted along the food chain, from production to consumption (Affognon et al., 2015; Hodges et al., 2011; Kitinoja et al., 2018). Regardless of the point of occurrence, the environmental impact of food losses and waste is immense (FAO, 2013a). Moreover, with increase in globalization, food products and their raw ingredients are transported and/or further processed around the world, making food safety[1] a relevant issue in assuring the health of the global consumer (Tian et al., 2016). Climate change with rising global temperatures and extreme heat stress as well as the increasingly scarce and unequally distributed global resources negatively affects food security[2] (Schmidhuber & Tubiello, 2007; Tian et al., 2016). After a prolonged decline, world hunger appears to be on the rise again (UN, 2016). Paradoxically, as billions suffer food insecurity through lack of food, nearly 2 billion adults are overweight (FAO & WHO, 2018). Malnutrition – encompassing undernourishment, micronutrient deficiency, overweight and obesity (FAO, 2017) – occurs around the world. These megatrends heavily impact each link of the agri-food supply chain and are causing the world food system to reach its limits. Thus, it raises the question how we can feed the world in future.

Related to the world development trends, a sustainable transformation of global food systems has been declared a major field of action in order to reach the sustainably development goals (SDGs) by the United Nations (UN, 2016). To reach "zero hunger" (SDG 2) in 2050 (UN, 2016) by achieving food safety and security, both the agricultural production and food manufacturing systems will be challenged to use less resources and to produce greater quantities of foods. Further, the global food system needs to address food preferences of all populations by developing innovative new foods with high nutritional value, long shelf lives, and which also should be conveniently transportable (Augustin et al., 2016; Floros et al., 2010). Food production and trading needs to reduce the environmental and climate footprint (FAO, 2017), for example, by using alternative food processing technologies (Augustin et al., 2016), paying greater attention toward reducing postharvest losses (Kitinoja et al., 2018) and manufacturing wastage (Floros et al., 2010). These goals are also in line with the SDG 12 to "ensure sustainable consumption and productions patterns" (UN, 2016). Although new food technologies also affect other SDGs, they mainly target contributing to SDG 2 and 12. How new food technologies address challenges in the food production, is presented in the following section 1.1.2.

[1] Food safety is "about producing, handling, storing and preparing food in such a way as to prevent infection and contamination in the food production chain, and to help ensure that food quality and wholesomeness are maintained to promote good health", WHO (2015).

[2] Food security exists when "all people, at all times have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life", FAO (2018) c.f. FAO World Food Summit (1996).

1.1.2 New food technologies in the food system

Assuring food safety and security today and in the future requires technological solutions through multidisciplinary collaborative efforts across agriculture, food industry, governance, and research. These solutions need to supply and provide access of sufficient nutrition to the global population for maintaining health and have to be acceptable to society (Augustin et al., 2016). This section presents several new food technologies that bear the potential to meet future food needs, at best sustainably. Within the research landscape highly discussed technologies are introduced in the following sections of this chapter. Thereby, technologies are distinguished due to their level in the food supply chain, i.e. (a) technologies at breeding and growth phase, (b) technologies at processing phase, and (c) technologies between production steps.

(a) Technologies at breeding and growth phase

A promising strategy to provide nutritional valuable food is biofortification. It improves the nutritional content of staple food crops by breeding varieties with a richer level of important micronutrients (e.g. vitamin A, zinc, iron) than conventional crops (Birol et al., 2015; Bouis & Saltzman, 2017; Hirschi, 2009; Nestel et al., 2006; Saltzman et al., 2013). Currently, three different methods are used, i.e. conventional plant breeding, agronomic approaches such as soil- or leaf-fertilization, and genetic engineering (Saltzman et al., 2013; Talsma et al., 2013; Van der Straeten et al., 2017). Biofortification is considered a highly cost-effective strategy that could target vulnerable populations in rural areas, who produce and consume staple food crops in significant quantities (De Steur et al., 2017c). They may not have access to other nutrition interventions such as supplementation and fortification, which mainly target urban populations that consume processed food (Birol et al., 2015).

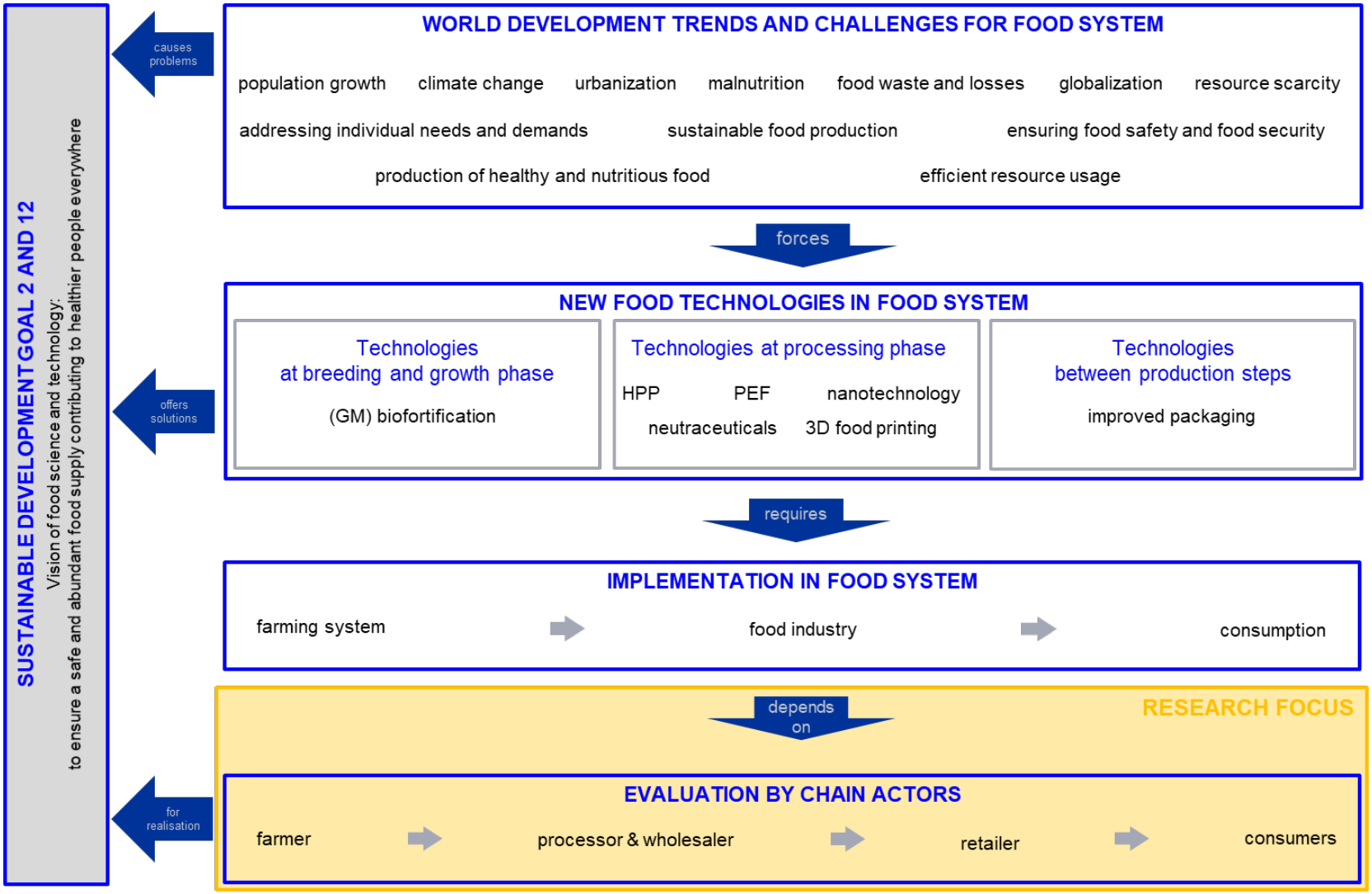

Figure 1.1: Research motivation - world developments and its proposed solutions.

Sources: Affognon et al. (2015); Augustin et al. (2016); FAO (2017); Floros et al. (2010); Godfray et al. (2010); Hodges et al. (2011); Misra et al. (2017); Santeramo et al. (2018).

(b) Technologies at processing phase

Over the past decades, various food processing technologies have been explored and implemented to provide a high variety of safe, fresher-tasting, longer lasting (shelf-life), convenient and nutritive food products, while diminishing waste and reducing the use of energy and water (Augustin et al., 2016; Floros et al., 2010; Lusk et al., 2014; Misra et al., 2017). In general, food processing refers to any deliberate change in a food that occurs before it is available (Augustin et al., 2016) and thereby links agricultural production to consumption (Floros et al., 2010). In more detail, Dwyer et al. (2012) offers a more comprehensive definition of food processing:

> *"Any food other than a raw agricultural commodity, including any raw agricultural commodity that has been subject to washing, cleaning, milling, cutting, chopping, heating, pasteurizing, blanching, cooking, canning, freezing, curing, dehydrating, mixing, packaging, or other procedures that alter the food from its natural state. Processing also may include the addition of other ingredients to the food, such as preservatives, flavors, nutrients, and other food additives or substances approved for use in food products, such as salt, sugars and fats. Processing of foods, including the addition of ingredients, may reduce, increase, or leave unaffected the nutritional characteristics of raw agricultural commodities"* (p. 537).

Traditional food processes like freezing, drying, fermentation, canning, and along with industrialization in the 19th century also pasteurization and sterilization focus on preservation (Augustin et al., 2016; Floros et al., 2010; Lusk et al., 2014; Monteiro et al., 2010). Latest developments and technologies are, among others, cold plasma, pulsed electric fields (PEF), high-pressure processing (HPP), ultraviolet irradiation, microwave-heating and nanotechnology (La Morales-de Peña et al., 2019; Weaver et al., 2014) and recently 3D food printing (Dankar et al., 2018; Lipton et al., 2015; Lipton, 2017; Liu et al., 2017). These new food technologies mainly treat the food more gently compared to the traditional pasteurization process in order to maintain the nutritional content in the food, extending shelf-live and ensuring food safety.

New product technologies to be considered at the processing stage are neutraceuticals. A nutraceutical is "any substance that is a food or part of a food and provides medical or health benefits, including the prevention and treatment of disease" (DeFelice, 1995, p.59). This definition includes food fortification, and in particular, functional food and dietary supplements.

(c) Technologies between production steps

To ensure food safety and security, technologies between the production steps are also necessary. Technologies such as better storage possibilities, more effective (cold) supply chains, and infrastructure for transportation (Hodges et al., 2011), mainly aim to reduce food losses. This increases food availability without requiring additional production resources (Affognon et al., 2015; Hodges et al., 2011; Lipinski et al., 2013). Further, packaging plays a

central role to ensure that the food is not damaged during transportation, and is delivered safely to consumers (Floros et al., 2010; Kitinoja, 2013; Lipinski et al., 2013).

All these new food technologies can have an impact to tackle the challenges in food production (as presented in 1.1.1). However, their market success depends on the evaluation by the relevant actors in the food chain which is addressed in the next section 1.1.3.

1.1.3 Evaluation of new food technologies by supply chain actors

The gobal food system is made up of food system activities (growing, harvesting, processing, packaging, transporting, marketing, consuming, and disposing of food and food-related items), and food system actors, all influenced by their own set of driving forces and goals (Ingram, 2011; Zurek et al., 2018). Central part of the food system is the food supply chain, referring to the processes (production, processing, distribution, retail) that may be involved before food reaches the end-consumer (Garnett et al., 2016).

According to Michalak & Schroeder (2011), key actors in the food supply chain are farmers, processors, retailers and consumers. However, the number of relevant actors in an innovation implementation process depends on the type of innovation. For example, as illustrated in Figure 1.2, packaging is subject from harvest over transportation, storage and selling to consumption. Further, regarding novel food technologies, implementation of GM food innovations commences at the farmers' level while processing technologies such as HPP starts at the level of processors (up to consumers). Finally, consumers are confronted with new food products that are the physical outcome of new food technologies. The level of which the technology is introduced in the food supply chain determines the key actors relevant for food technology evaluation research. How these chain actors evaluate the technology drives its success to be implemented in the food system (Augustin et al., 2016; Rogers, 1995). This argument can be explained by the theory of microfoundations.

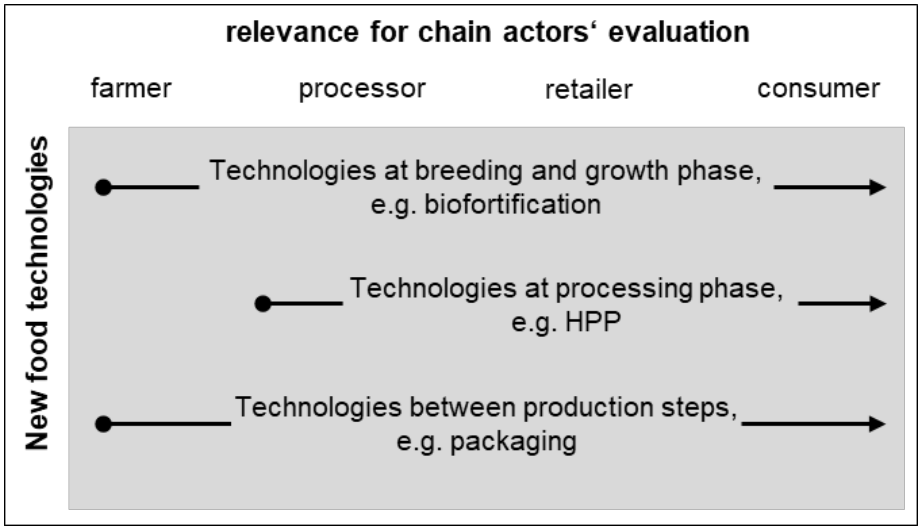

Figure 1.2: Relevant chain actors for food innovation implementation process.
Source: Own illustration.

The theory of microfoundations states that the causal relationship between two macro phenomena is fundamentally explained by the micro level phenomena. Thus, in order to determine the macro outcome developments in the food system, lower level unobserved factors need to be identified (Coleman, 1990; Felin et al., 2015). Accordingly, the causal relationship between market entry and successful diffusion[3] of new food technologies (macro phenomena), is mediated by the beliefs and attitudes of the individuals at the micro level (Figure 1.3). For example, attitudes toward new technologies explain the actual use of improved packaging, the adoption of new food technologies or the final consumption of new food products. These actions, in turn, explain the final macro outcome of developments in the food system, i.e. whether they will be successfully implemented in the food supply chain, and to what extent they are impacting the global food safety and security goal. Based on this broad research heuristic, it is crucial to focus on individuals' action conditions and how they are determining the final action.

Within the literature on chain actors' evaluation of food technologies, there is a huge variety of different outcome (or dependent) variables, as also indicated in a meta-analysis on consumer evaluation of GM food (Frewer et al., 2013). Behavioral intention (intention to perform a behavior), for example, is included in the renowned Theory of Planned Behavior (Ajzen, 1991), together with attitude, in order to explain (future) behavior. Willingness to pay, another concept that is linked to chain actor evaluation, is elicited through preference methods

[3] Diffusion refers to "the process in which an innovation is communicated through certain channels over time among the members of a social system" Rogers (1995), p.5.

and is distinct from an attitude someone holds about, for example, a food technology. Even though these concepts clearly measure different aspects of chain actor evaluation, they are often used interchangeably (Frewer et al., 2013; Mogendi et al., 2016b), resulting in the need to use a more general concept. According to Hess et al. (2016) and Mogendi et al. (2016b), evaluation is that kind of comprehensive concept for chain actors' views on new food technologies and represents indicators such as likelihood or intention to perform a behavior, perceived benefits/risks, willingness to pay, acceptance/adoption, and attitudes (Table 1.1). These indicators do not focus on actual behavior, but rather on chain actors' willingness to perform a behavior which is a predictor for the former.

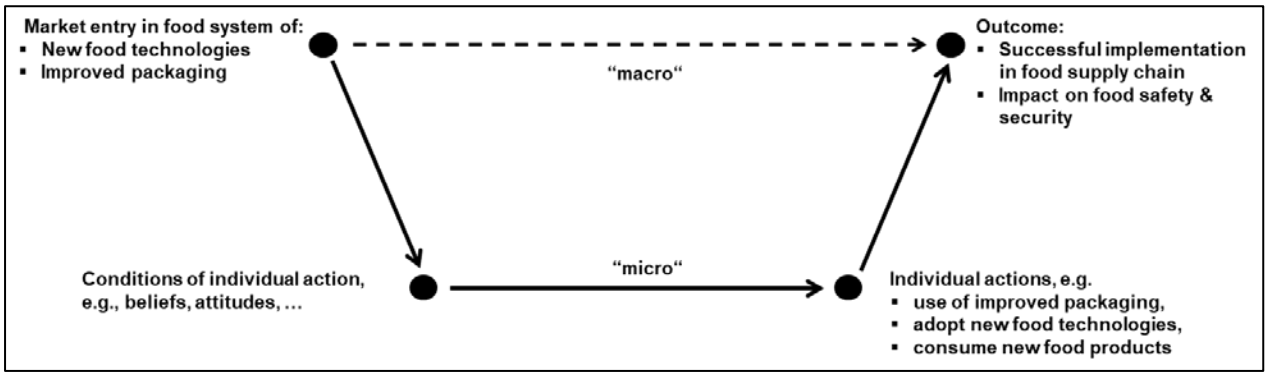

Figure 1.3: The Coleman's Bathtub in the context of innovations in the food system.
Source: Based on Coleman (1990).

To this end, the outcome and success of the previously presented new food technologies (section 1.1.2) depend on the evaluation of the individuals, i.e. the relevant actors in the food supply chain. Understanding factors influencing individual decision making helps industry and policy makers developing better implementation strategies. The latter influences the impact of new food technologies on tackling challenges in the food system, e.g. to ensure food security. Thus, investigating the food technology evaluation through the perspective of relevant food chain actors is of high research interest. This research topic raises, for instance, following questions: Which attitudes affect farmers' willingness to use improved agricultural practices such as biofortification technologies? What determines traders' adoption of improved handling practices such as improved packaging? Which factors are influencing processors' decision to implement new food technologies, such as HPP? Which attributes describes best consumers' behavior of buying and eating new food products? To answer such questions, social science research introduced various theories that are subject of section 1.2 which help to analyze chain actors' evaluation toward new food technologies.

Table 1.1: Overview of concepts to measure chain actors' evaluation of new food technology.

Concept	Definition
Acceptance	Acceptance is the stage at which point individuals are held to form a favorable or unfavorable attitude toward the innovation and to take a decision to adopt or reject an innovation.
Adoption	Adoption is a decision (process) to make full use of an innovation as the best course of action available.
Rejection	Rejection is a decision not to adopt an innovation.
Perception	Perception can be viewed as an external factor, which concerns one's view, understanding, belief, or reaction to an innovation.
Attitude	Attitudes are defined as an overall evaluation of an innovation that is based on cognitive, affective, and behavioral information.
Intention	Intention toward an innovation indicates of how hard people are willing to try, of how much of an effort they are planning to exert, in order to perform the behavior, e.g. using an innovation.
Willingness-to-pay	Willingness-to-pay is the highest price an individual is willing to accept to pay for an innovation.
Evaluation	Evaluation is defined as the assessment of the positive and/or negative qualities of an innovation.

Remark: In general, a high variety of different definitions of the above mentioned concepts exist. Thus, this table is not universal, but presents overall accepted definitions.

Source: The table is an own compilation based on: Ajzen (1991); Breidert (2006); Jarvis & Petty (1996); Johnson (2010); Maio & Haddock (2015); Rogers (1995); Upham et al. (2015).

1.2 Theories, models and concepts to investigate on chain actors' evaluation research

In order to analyze the determinants of individuals' behavior and action, social science research draws on several theories. A general theoretical background including definitions of important terminologies is described in this section.

Theories, in general, refer to "a set of concepts plus the interrelationships that are assumed to exist among these concepts" (Selltiz et al., 1976, p.16). Moreover, theories are "explanations of recurrent patterns or regularities in social life" (Blaikie & Priest, 2019, p.133) as they provide answers to questions like why people behave in the way they do in particular social contexts and explain specific patterns, similarities and differences in social life (Blaikie & Priest, 2019). Within the human behavior literature, a theory can be distinguished between explanatory theory (theory of the problem) and change theory (theory of action) (Glanz et al., 2008). The former predicts behaviors under defined condition (Glanz et al., 2008) by identifying the underlying factors, which influence the behavior (Darnton, 2008). Contrarily, change theory "show[s] how behaviors change over time, and can be changed" (Darnton,

2008, p.1) for guiding the development of interventions such as adopting new behaviors (Glanz et al., 2008). Although both theories have different foci, they are highly complementary (Glanz et al., 2008) and have considerable overlaps (Darnton, 2008).

Models are building blocks of theory and a source of testable hypotheses (Hair et al., 2014; Schütz, 1963). They are necessary to grasp reality by abstractly describing its structure and simplifying it (Glanz et al., 2008; Rodrik, 2015). Hence, models are never universally true, but there is truth in models (Derman, 2011; Rodrik, 2015). Behavioral – explanatory – models are designed to predict and explain specific behaviors by showing linear relationships between influencing psychological factors and its relative importance as a series of arrows (Darnton, 2008; Van der Linden, 2013). Thereby, a model is a completely closed, deductive system of propositions that identifies the interrelationships among the concepts and refers to a formal theory or definition of what is being studied (Glanz et al., 2008). Alternatively, models of change depict more commonly generic processes by applying circling and incorporating feedback loops (Darnton, 2008). Major components of a model are constructs, i.e. specifically developed, adopted and defined concepts for use in a particular theory (Glanz et al. 2008). For example, subjective normative beliefs is a construct within the Theory of Reasoned Action (Ajzen & Fishbein, 1977; Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975) and self-efficacy is precisely defined in the context of the Protection Motivation Theory (Rogers, 1975). The abstract concepts cannot be measured directly, thus, variables are used as operational measurements by assessing different attributes of the construct of interest (Bryman, 2016). It should be noted that the terms ‘theory’ and ‘models’ are often used interchangeably or even combined like ‘theoretical models’ (Blaikie & Priest, 2019).

For the collection and analysis of data needed for assessing theories and models, several frameworks or research designs, are classified. Among others, experimental and cross-sectional designs are prominent research designs (Blaikie & Priest, 2019; Bryman, 2016). While the latter is dominantly applied for testing explanatory behavioral theory, the former can be used for assessing change theory. In experimental designs, independent variables are manipulated in order to determine whether it does have an influence on the dependent variable and, thus, there is little ambiguity about the direction of causal influence. Cross-sectional designs refer to survey designs that “entails the collection of data on a sample of cases [e.g. people] and at a single point in time in order to collect a body of quantitative (…) data in connection with [at least] two (…) variables (…), which are then examined to detect patterns of association” (Bryman, 2016, p.53). As there is no time ordering to the variables in the cross-sectional research design, it creates the problem of ambiguity about the direction of causal influences and, thus, it is only possible to examine relationships between variables, but not to discover causal relationships (Bryman, 2016). Although cross-sectional designs of testing

models fail to determine causal relationships, they dominate research approaches in the social sciences (Beins, 2017), because the underlying models are a "quick (…) [but imprecise] way of organising a lot of information in order to make more theoretical statements possible" (Triandis, 1977). Moreover, Mitchell & Jolley (2007) discussed several reasons why scientists prefer theory to common sense (non-theoretical based research). They stated theories tend to be more consistent internally and with existing facts, summarize and organize a great deal of information, can be applied to a wide range of situations, tend to be parsimonious and are often more testable than common sense.

Behaviorism sees behavior as contingent, i.e. as a response to an antecedent and driven by the consequences (Webster, 2019). Hence, it implies that behavior depends on the response of experiences, thoughts as well as expectations, and thus, is contingent upon context (Luhmann, 1984). In consequence, there are numerous social-psychological theories and models of behavior (for an overview see Darnton, 2008; Hillmer, 2009; Lusk et al., 2014) that are derived from a specific behavioral context and tend to work best in that context. For example, the Norm Activation Theory (Schwartz, 1977) is originally developed in the context of altruistic behavior and the Health Belief Model (Rosenstock, 1960; Rosenstock, 1974; Strecher & Rosenstock, 1997) is established for predicting preventative health behaviors. Notably, some behavioral models such as the Theory of Planned Behavior (Ajzen, 1991), the Theory of Interpersonal Behavior (Triandis, 1977) and the Technology Acceptance Model (Davis, 1986) have wider applicability, however, overall these models are better at explaining behaviors in some areas than in others (Ajzen, 1991; Armitage & Conner, 2001; Darnton, 2008; Marangunić & Granić, 2015). These theories and models are developed to better understand individual action and behavior at the micro-level in order to evaluate the potential outcome of a macro-phenomenon (see section 1.1.3 and Figure 1.3) and can be considered to be partial models[4] (Klein & Scholl, 2011). Using theories that are well-established and validated in different research settings is advantageous for several reasons. Theory-based research not only has the advantage of being relevant to the theory's explanation of events, but also to the findings of other researchers. This makes findings from various research settings and studies comparable (Mitchell & Jolley, 2007). The application of such models in the context of novel food technologies can lead to new research insights. It would be interesting to identify which models are applied in that particular context and how they operate in specific contexts related to food behavioral topics. Knowing that behavioral models are dominating research in social sciences, it is of high interest to investigate the status-quo of food technology evaluation analysis and further to explore the applicability of specific models

[4] Partial models are limited to a specific section of the real system. In a total model, however, a real system is fully modeled in its entirety, Klein & Scholl (2011).

and factors of importance in a particular context. The next section 1.3 investigates further in the underlying research gaps and questions of this doctoral thesis.

1.3 Research gaps, objectives and questions

The research landscape on food technology evaluation has grown over the years, using a high diversity of different theoretical models, notably since the invention of pasteurization in 1856. The research focuses on the evolutionary skepticism of new foods by humans (Lusk et al., 2014). This is especially shown by the last Eurobarometer survey on the life sciences from 2010. Results indicate that most new food technologies such as genetically modified or nanotechnology food are rejected (European Commission, 2010). Hence, research focuses mostly on consumer evaluation. However, the diffusion of new food technology requires the positive evaluation of all involved supply chain actors. To this end, this thesis identifies two main research gaps:

- To systematically analyze the diverse theoretical approaches in order to develop a framework for the analysis of new food technology evaluation.
- To broaden the scope beyond consumers to other supply chain actors in the context of new food technology evaluation.

Based on the literature background in section 1.1 and 1.2 and the above mentioned research gaps, the overall aim of this thesis is to *advance the understanding of food technology evaluation across supply chain actors*. This is explored through the following two objectives:

Objective 1: *To develop a scientifically underpinned conceptual model for analysis of food technology evaluation.*

Objective 2: *To empirically analyze food technology evaluation at consumer and trader level with different models.*

The two objectives are investigated in this thesis by exploring several research questions, described in the following sections 1.3.1 and 1.3.2. Whereas for objective 1, the research focus is rather broad as several supply chain actors, new food technologies, and countries are considered, for the empirical research (objective 2) this thesis analyzes specific cases. Hence, empirical studies focus on consumes' and traders' evaluation in order to investigate the demand and supply side of the food chain. Further, Germany and Tanzania are chosen as research settings dependent on the selected food technologies, i.e. 3D food printer, dietary supplements and food packaging. The reasonings behind the cases are in more detail explored in section 1.3.2.

1.3.1 Objective 1: Developing a scientifically underpinned conceptual model for analysis of food technology evaluation

Broadly, research on food technology evaluation analyzes specific examples of food technologies such as HPP or functional food, rather than the overall technology evaluation concept, i.e. chain actors' reactions toward new food technologies in general. Currently, literature on new food technology evaluation appears to be scattered due to their heterogeneous focus on technologies, but quite homogeneous focus on consumers. Therefore, a comprehensive overview of literature seems necessary to understand the status quo of research on new food technology evaluation while synthesizing findings about different technologies and going beyond consumer research. In addition, from a theoretical perspective, a large variety of different theoretical approaches of evaluation research exist. This raises the question "What well-established theoretical models are applied in the context of new food technology evaluation and how it will help to contribute to a better understanding?". Furthermore, past literature reviews did not focus on different research settings such as the investigated food technology and supply chain actor. To this end, this study (chapter 2) explores the following research questions:

RQ 1: *Which research settings and theoretically models are used to analyze food technology evaluation?*

RQ 1.1: *What types of existing food technologies are commonly applied in model based evaluation studies?*

RQ 1.2: *What levels of the food supply chain are targeted in model based food technology evaluation studies?*

RQ 1.3: *What well-established theoretical models have been used to examine food technology evaluation behavior along the supply chain?*

Evaluation research, also in the context of new food technology evaluation, applies well-established behavioral theories. Nonetheless, a number of studies develop study-specific models including various factors influencing the targeted behavior. This raises the question if well-known theories are suitable in the context of new food evaluation research and if they need to be modified. An extensive overview of factors that are applied to understand new food technology evaluation will enhance the knowledge of important factors in this context, targeting how an appropriate model might look like. Therefore, the present study (chapter 3) seeks to fill this research gap by exploring the following research questions:

RQ 2: *What are key factors of supply chain actors' new food technology evaluation?*

RQ 2.1: *What are most often used descriptive and psychological factors within food technology evaluation research?*

RQ 2.2: *Which factors show significant relationships to one of the indicators of food evaluation?*

Contributions – Systematic literature reviews of publications on (1) theoretical well-known models, and (2) factors applied in the context of new food technology evaluation are provided to explore these research questions. Future research avenues are identified and proposed to guide further research on food technologies evaluation focusing on relevant food chain actors and technologies while using relevant factors. Specifically, these research questions aim to:

i) quantify targeting technologies and actors within the domain of new food technology evaluation;

ii) deduce theoretical lenses that are applied to studies on chain actors' new food technology evaluation;

iii) identify research gaps of new food technology evaluation that need to be addressed in future studies with regard to technology, supply chain actors and research methodology.

Derived from the identified research gaps, the following objective on empirical analysis at consumer and trader level targets to fill gaps in the food technology evaluation research.

1.3.2 Objective 2: Empirical analysis of consumers' and traders' food technology evaluation

Research on new food technology evaluation depends on several key features such as the targeted technology or innovation, the supply chain actor, and the research design (Figure 1.4).

Thus, the spectrum on possible research foci is tremendous and broad. In general, the aim of this thesis is to apply different theoretical frameworks to specific actors in the supply chain in order to better understand their new food technology evaluation and simultaneously examine the performance of well-established theories. Thereby, this thesis focuses on three different technologies, i.e. (a) 3D food printer, (b) dietary supplements and (c) food packaging. Research was undertaken with two supply chain actors, i.e. consumer and trader, by applying mainly cross-sectional designs for collecting data. The reasons behind the combined research foci are derived hereafter, respectively for each research question.

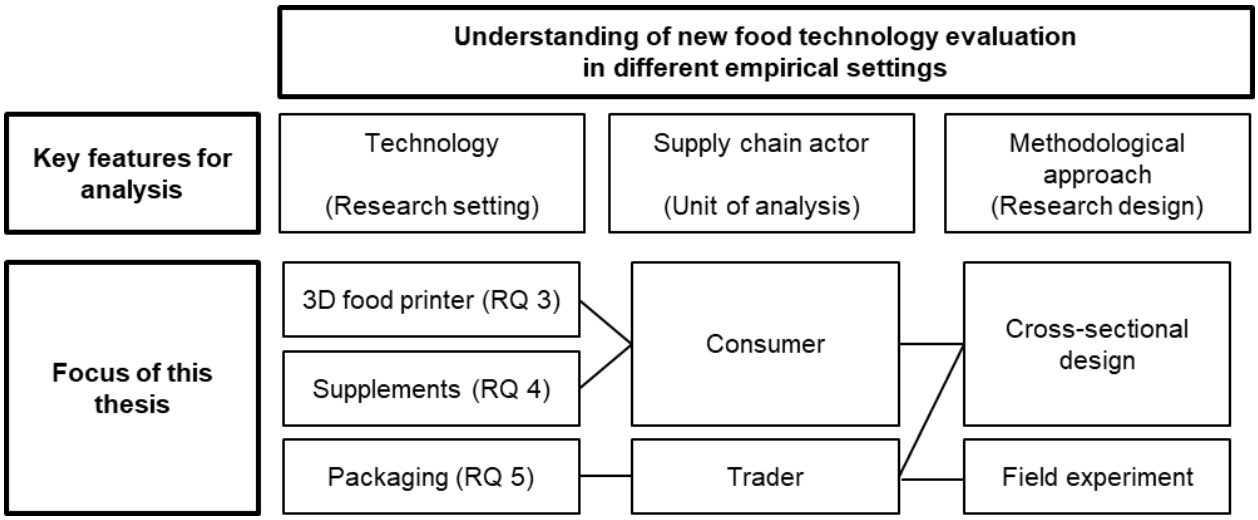

Figure 1.4: Key features for the empirical analysis of new food technology evaluation.
Source: Own illustration.

(a) 3D food printer

Various food processors and technology innovators are developing numerous food technologies. A recent development is the 3D food printing technology, which is expected to present many opportunities to revolutionize the global food industry (Research & Markets, 2018). 3D food printers are at a nascent stage and focused predominantly on intricate, sugar-heavy confections until 2014. Then, several technological advancements made in the field of 3D food printing have resulted in an increased level of food personalization in terms of flavor, texture, shape, size, and design while customized nutrition and ingredients (Research & Markets, 2018). North America and Europe are the two prominent markets for food 3D printing as mass customization of commoditized products and creating complex food products quickly and inexpensively is possible (Research and Markets, 2018). 3D food printers have the potential to be implemented at different stages in the food chain, i.e. food industry, restaurants, supermarkets, but also at end-users' homes. However, due to the novelty of the technology, little is known about consumers' evaluation of 3D food printing. In addition to explore on the understanding of consumers' response to 3D-printed food, it was used as a case to test a proposed Food Technology Acceptance Model developed from the systematic literature reviews conducted for objective 1 (RQ 1 and 2). This model includes widely used and significant factors that describe consumers' evaluation of new food technologies. It can be applied to enhance the understanding of consumers' evaluation of 3D-printed food in comparison to consumers' evaluation of other new food technologies.

According to a forecast analysis by Research & Markets (2018), the European market is identified as a promising diffusion area for 3D food printers. Especially Germany is one of the first countries that uses 3D food printer already in nursery homes (Lupton, 2017). However, little is known about German consumers evaluation of 3D food printer. To this end, this thesis (see chapter 4) analyzes the following research questions:

RQ 3: *What determines consumers' evaluation toward new food technologies exemplified on 3D food printer?*

RQ 3.1: *What drives consumers' evaluation of 3D-printed food?*

RQ 3.2: *How will consumers' evaluations of 3D-printed food differ to other new food technologies?*

RQ 3.3: *How will the model prediction of a proposed Food Technology Acceptance Model differ to a well-known theory represented by the Theory of Planned Behavior?*

(b) Dietary supplements

Among the drivers of innovation in the European food industry related to consumer expectations, health accounts for nearly one in four innovations launched and is the most dynamic driver of food innovation in terms of growth (FoodDrinkEurope, 2016). Hence, products with dominant and promoted health benefits are nutraceuticals such as functional food as well as dietary supplements. Functional food can be interpreted as the carrier of functional ingredients with certain health benefits (Bornkessel et al., 2014). Nonetheless, functional foods remain ordinary food as part of a normal food pattern (Diplock et al., 1999). Consequently, pills or capsules – the form of dietary supplements – do not belong to the category of functional food (Diplock et al., 1999). Dietary supplements, nevertheless, are considered to be food due to the rather broad definition of food by the EU regulation (EC) No 178/2002 that states that 'food' is "any substance or product, whether processed, partially processed or unprocessed, intended to be, or reasonably expected to be ingested by humans" (European Commission, 2002, Article 2). Thus, dietary supplements are considered to be food, however, they are no medical products that claim to restore, correct or modify the body's physiological functions (European Commission, 2002a).

Although increasing dietary diversity is generally regarded as the most desirable and sustainable option for a long-term healthy eating behavior, it takes some time to be implemented. As such dietary supplements, i.e. supplying an optimal amount of specific

nutrients in a highly absorbable form, are a fast way to control deficiency in individuals (WHO and FAO, 2006). For example, in Germany, more than one fourth of the population takes supplements in order to mainly compensate their apparent poor health, but also to maintain their good health (Max Rubner-Institut, 2008).

As the health attribute of food is regarded to be an important factor triggering consumers' food technology evaluation (Barrena et al., 2017; Bogue et al., 2005; Sonne et al., 2012), the level of the health benefits promoted by a product may influence the involvement of consumers' purchasing behavior. Thereby, involvement is a prominent factor used to explain consumers' behavior in the context of food products (Kröber-Riel et al., 2009). This study aims to explore the level of involvement of dietary supplements as compared to ordinary food products and the factors influencing consumers' involvement. Thus, it (see chapter 5) addresses the following research questions:

RQ 4: *What determines consumers' evaluation toward new food technologies exemplified on dietary supplements?*

RQ 4.1: *To what extent are dietary supplements subject to a higher level of involvement than 'ordinary food' products?*

RQ 4.2: *Which factors represent potential determinants of consumer involvement in dietary supplements?*

(c) Food packaging

Although consumers have the power to co-determine the commercialization of products, acceptance and adoption is required at all levels of the food supply chain for a functioning global food system. One important actor at the supply side is the trader who is connecting different supply chain actors. Traders play an key role for maintaining the freshness, quality and safety of the food (Handayati et al., 2015). Especially in developing countries, poor postharvest handling and trading systems cause high food losses (Shewfelt et al., 2014), e.g. by the use of poor packaging materials (Kereth et al., 2013). Consequently, reducing postharvest losses by, e.g. improved packaging, can contribute to ensure food security and may have the capability to generate increased income (Kitinoja, 2013). Increasing income, measured by, e.g. perceived net benefits, is an important adoption factor for new technologies at farmer and trader level in developing countries (Benzing & Chu, 2009; Feder et al., 1985). However, little is known about the effectiveness of different packaging improvements such as lining materials as well as of traders' evaluation toward the enhanced packaging. To close this gap, this thesis (chapter 6) investigates the case of improved tomato packaging and its evaluation by traders in Tanzania. The case of tomatoes was chosen because they are easily

damaged due to its consistency, and require appropriate packaging. Further, tomato production is an important market in Tanzania but tomato losses are high (Kereth et al., 2013). Thus, improving packaging is relevant for ensuring food safety and security. Therefore, chapter 6 explores the following research questions:

RQ 5: *What determines traders' evaluation toward new food technologies exemplified on an improved tomato packaging?*

RQ 5.1: *What is the effectiveness of introducing different lining material to enhance tomato packaging?*

RQ 5.2: *To what extent perceive traders net benefit of improved tomato packaging as determinant for willingness to adopt the improved tomato packaging?*

Furthermore, high tomato losses in the fruit supply chain can be prevented by the use of improved or new technologies. However, these technologies are usually not adopted where evaluation behavior is rather unknown. Evaluation research of improved postharvest handling and trading practices tend to focus on the farm level while analyzing psychological factors influencing adoption behavior (Matata et al., 2010; Nkonya et al., 1997; Tenge et al., 2004; Yamano et al., 2015). However, little is known about traders' evaluation of improved packaging materials, particularly in relation to their psychological constructs. Using the example of a tomato supply chain in Tanzania, the present study (chapter 7) seeks to fill this research gap by exploring the following research questions:

RQ 5.3: *What are the main psychological factors driving traders' evaluation of a new type of wooden crate with lining?*

RQ 5.4: *What are main explanatory factors that affect the psychological constructs of the evaluation of improved packaging?*

Contributions – Empirical research is conducted to investigate the above research questions RQ 3, RQ 4, and RQ 5 by collecting data via an online survey (chapter 4), structured telephone interviews (chapter 5) and structured face-to-face interviews at the market place (chapter 6 and chapter 7). In addition, for the study in chapter 6, a field experiment was conducted to explore the effectiveness of lining in wooden crates. The surveys are based on well-established theoretical models and important factors for analyzing new food technology evaluation as identified in the literature reviews of chapter 2 and chapter 3. The analysis is mainly based on structural equation modeling. In particular, this thesis aims to advance the state-of-the-art with regard to:

i) assessing consumers' and traders' evaluation of three different technologies (i.e. 3D food printer, dietary supplements, improved packaging) that are promising to positively impact future food strategies and contribute to food safety and security;

ii) analyzing different well-established theoretical models in diverse contexts, i.e. different technologies evaluated by different chain actors;

iii) testing relevant factors important for new food technology evaluation up to the development of a proposed Food Technology Acceptance Model and comparing it to the well-known Theory of Planned Behavior.

By examining these research questions, this thesis provides a comprehensive overview of different factors used in the new food technology evaluation research. Thereby, each chapter has a specific focus and its overall connection is visualized in Figure 1.5. Since the above mentioned research questions use different chain actors' perspectives to analyze new food technology evaluation, they are explored by employing different theoretical concepts, research approaches and methods. The next section explains the research approaches and methods that are utilized to study new food technology evaluation from the perspectives of different chain actors.

1.4 Research approaches and methods

Table 1.2 gives an overview of the study designs. It provides an insight into the perspectives analyzed, the data used, and the research setting and methods for data analysis that are employed in the thesis.

On a general note, this thesis used a mix of methods to collect and analyze data in order to answer stated research questions and, ultimately, to reach the objectives. Thereby, this thesis investigates on the theoretical perspective as well as on the empirical analysis of consumers' and traders' evaluation of different food technologies. The research approaches and methods employed for specific aspects of chain actors' food technology evaluation are explained in the following subchapters.

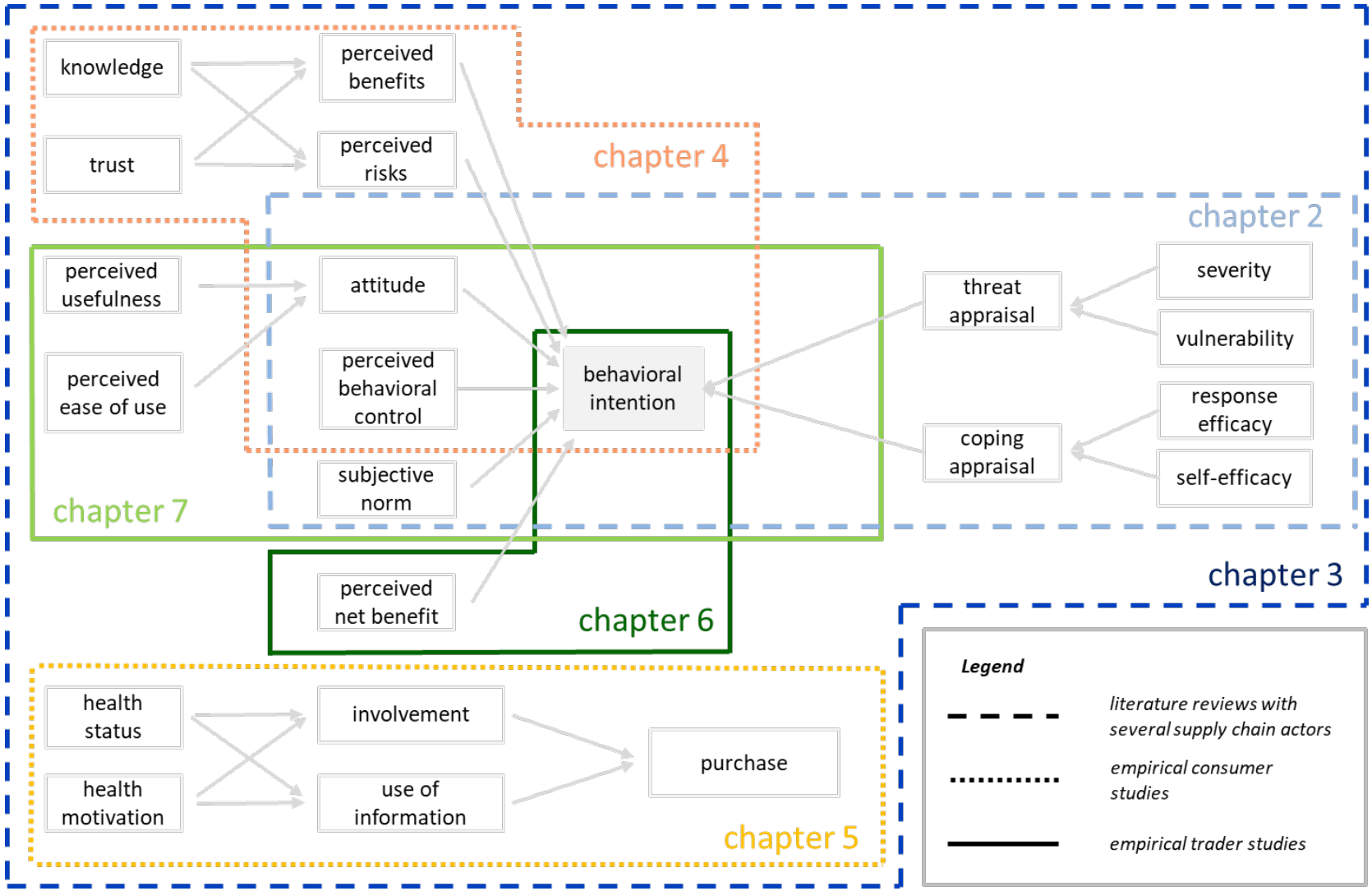

Figure 1.5: Structural overview of factors within this thesis.

Source: Own illustration.

Table 1.2: Overview of study design.

Aspects analyzed		Chapter	Unit of analysis	Sample used	Research setting	Methodological approach	Publication status
	Theoretical perspectives of new food technology evaluation	2	Food supply chain	183 publications from Web of Science (27 paper in-depth)	Various new food technologies, around the world	Qualitative approach: Systematic literature review	Under review (2019) in: International Journal of Innovation and Sustainable Development.
		3	Food supply chain	183 publications from Web of Science	Various new food technologies, around the world	Qualitative approach: Systematic literature review, qualitative content analysis, network analysis	Published 2019 in: Comprehensive Reviews in Food Science and Food Safety 18 (3): 798-816.
	Empirical analysis on chain actors 'evaluation of new food technologies	4	Consumer	Online survey with 463 consumers	3D food printer, Germany	Quantitative approach: Partial Least Squares Structural Equation Modeling	In preparation for: Journal of Environmental Management
		5	Consumer	Structured telephone interviews with 350 consumers	Dietary supplements, Germany	Quantitative approach: Partial Least Squares Structural Equation Modeling	Published 2019 in: PharmaNutrition 9: 100157.
		6	Trader	Field experiment + structured face-to-face interviews with 80 tomato traders	Improved tomato packaging, Tanzania	Quantitative approach: On-station trial, economic cost-benefit analysis, correlation analysis	Published 2016 in: International Journal of Vegetable Science 22 (6): 530–540.
		7	Trader	Structured face-to-face interviews with 80 tomato traders	Improved tomato packaging, Tanzania	Quantitative approach: Partial Least Squares Structural Equation Modeling	Published 2018 in: International Food and Agribusiness Management Review 21 (6): 771–790.

Source: Own illustration.

1.4.1 Models and factors applied in new food technology evaluation research

To investigate objective 1 of this thesis, a systematic literature review and a qualitative content analysis was applied as well as the approach of a network analysis was adapted. These methodologies are described in more detail in the following sections.

Systematic literature review (chapter 2 and 3) – For identifying the main theoretical models and factors used to explain chain actors' new food technology evaluation, chapters 2 and 3 applied a systematic review of literature that used a search strategy with general and specific key words related to "new food technologies" and "evaluation" and "chain actors". These reviews were of qualitative nature. A meta-analysis was not feasible due to the nature of the data. A systematic literature review uses explicit and rigorous criteria to identify, critically appraise and synthesize all relevant studies on a certain topic in order to answer a particular question (or set of questions) (Cronin et al., 2008; Garg et al., 2008; Onwuegbuzie et al., 2012; Petticrew & Roberts, 2006). Nevertheless, shortcomings of this method are related to subjectivity with respect to the choice of search terms, developing the inclusion and exclusion criteria, and the subsequent selection of studies (Garg et al., 2008). However, systematic literature reviews are still an effective method to identify the main research methodologies and designs that have been utilized, as well as to identify variables that are relevant to a particular topic. Further, systematic reviews can be used to distinguish what has already been undertaken and what needs to be undertaken, i.e. to identify knowledge gaps (Guzzo et al., 1987; Onwuegbuzie et al., 2012).

Qualitative content analysis (chapter 3) – This method is a standard approach for text analysis in social sciences by following a systematic and rule-based process (Hsieh & Shannon, 2005; Schilling, 2006). To reduce the amount of data, it was used to systematically group categories out of extracted factors rather than to analyze textual data. In detail, the qualitative content analysis develops code categories and names for categories that flow from the data themselves (so called inductive category development; Mayring, 2000), applies a quantitative counting and description of the categories, and further treats the counting as the detection of patterns to guide the further interpretation of the data (Morgan, 1993). While this approach remains subjective in nature in terms of coding and interpretation, it is appropriate when the available data and the research goal is to describe patterns in the data (Morgan, 1993).

Network analysis (chapter 3) – In addition, for analyzing the relationships between factors in chapter 3, the idea and illustration possibilities of network analysis were adapted in order to analyze and visualize the relationship between factors. A network analysis, generally, is the study of graphs that are mathematical structures to study relationships between discrete objects (Brandes & Erlebach, 2005). Thereby, a graph consists of nodes (or vertices) – in the

case of chapter 3, for example, this refers to concepts like ‘attitude’ or ‘trust in institutions’ –, and edges (or links). The latter is the visual representation of a relation or connection between two nodes, e.g. significant relationships between trust in institutions → attitude reported in the studies. The strength of the connection can be measured through the degree of in-, out-, and total-degree of nodes (Brinkmeier & Schank, 2005), e.g. trust in institutions has 6 incoming relationships, 87 outgoing relationships, in sum a total degree of 93. This underlying graph theory allows a high variety of different illustrations that visualize the network with its underlying relationships (or edges) between nodes. Hence, complex data can be illustrated in a compact form.

1.4.2 Empirical analysis of consumers’ and traders’ new food technology evaluation

Consumer studies (chapter 4 and 5) – To analyze consumers’ evaluation of new food technologies as exemplified on 3D food printer and dietary supplements as well as to test the respective models and proposed frameworks in the studies, quantitative approaches were applied. The empirical studies (chapter 4 and chapter 5) employ *descriptive statistics* such as mean, median and interquartile range as well as the method of *Wilcoxon-signed rank test* (Wilcoxon, 1945) and *Kruskal-Wallis test* (Kruskal & Wallis, 1952) to obtain preliminary results of the samples’ characteristics and their influences on the intention to consume or purchase the particular new food. Both tests – the Wilcoxon-signed rank and the Kruskal-Wallis test – are non-parametric tests, suitable to the non-normal distributed data in chapter 4 and chapter 5. Both tests are very similar as they both are based on rank data and measure whether there is a difference between samples. However, whereas the Wilcoxon signed-rank compares (pairwise) two independent samples and assesses whether the mean ranks of these two related samples differ, the Kruskal-Wallis test can be applied with more than two independent samples, but therefore cannot exactly state where the difference between the samples lie (Field, 2009).

Moreover, *Structural Equation Modeling (SEM) (chapter 4, 5 and 7)* was applied in order to investigate the factors influencing consumers’ intention to consume or purchase food products derived from new food technologies varied. Generally, SEM describes a multivariate technique of data analysis which allows to simultaneously examine a series of dependence relationships between (multidimensionally measured) latent variables as well as directly observed variables based on empirical data (Hair et al., 2014). In other words, SEM combines factor analysis and multiple regression analysis. Thereby, SEM is distinguished between the covariance-based techniques and variance-based techniques. The covariance-based structural equation modeling (CB-SEM) develops a theoretical covariance matrix based on a specified set of

structural equations. This technique focus to minimize the difference between the theoretical covariance matrix and the estimted covariance matrix (Reinartz et al., 2009). For the variance-based techniques, Partial Least Squares Structural Equation Modeling (PLS-SEM) is the most prominent representative. This technique aims to minimize the error terms (i.e. the residual variance) of the endogeneous constructs (Hair et al., 2014). Simulation studies show that differences between CB-SEM and PLS-SEM estimates are at very low levels under large conditions such as required large sample sizes and large numbers of indicators per latent variables (e.g. Reinartz et al., 2009). However, when to use which SEM technique is discussed in extant literature to a great extent. Hair et al. (2011) provides an extensive overview of rules of thumbs for selecting CB-SEM or PLS-SEM. Along with these rules of thumbs, this thesis implements the method of PLS-SEM due to its ability to analyze complex structural models (many constructs and many indicators). It works efficiently with smaller samples sizes and has less restrictive assumptions about the data, thus, it is suitable for non-parametric data distribution. Further, PLS-SEM is especially appropriate for research that is exploratory (theory development) or applies extension of an existing structural theory (Hair et al., 2011).

Trader studies (chapter 6 and 7) – To analyze traders' evaluation of new food technologies as exemplified on an improved tomato packaging as well as to test the proposed frameworks in the studies, quantitative approaches were applied. First of all, chapter 6 investigates how effective lining materials in wooden crates are to reduce damage to tomato fruit via a field-experiment (on-station trial). Further, a standard *cost-benefit analysis* approach was used to calculate the profitability of the linings. In addition, a field-level survey was designed to gain detailed information on tomato trading as well as to assess physical losses at the retail level. Lastly, this chapter investigated traders' subjective perception of alternative tomato packing material using lining in wooden crates at the wholesale market through applying, i.e. a *correlation analysis* between willingness to use wooden crate with lining and perceived net benefit. To explore the socio-psychological factors that influence adoption behavior of traders on new postharvest handling technology (improved packaging), a path analysis by using PLS-SEM was conducted.

1.5 Structure of the thesis

This thesis contains eight chapters and its organization with the connection and relationships between chapters is presented in Figure 1.6.

Chapter 1 states the research problem and derives research questions and objectives for understanding chain actors' evaluation of new food technologies. It explains the rationale for

conducting this research as well as the theoretical background of studying individuals' evaluation. Eventually, the overall research agenda and the underlying structure of this thesis are explained.

Chapter 2 assesses the theoretical perspective in new food technology evaluation research. It presents an overview of the current research on chain actors' new food technology evaluation by means of a systematic literature review. Theoretical approaches or models that are applied in studies on chain actors' new food technology evaluation are highlighted in this chapter. Based on the results, a future research agenda on chain actors' new food technology evaluation is proposed. This future research agenda forms the basis for studies presented in the next chapters.

Chapter 3 expands the methodological perspective of chapter 2 by focusing on the factors influencing chain actors' new food technology evaluation. It provides a systematic review of the psychological factors as well as chain actors' characteristics that are most often investigated in this research domain. The results of this comprehensive review form the basis for the empirical study presented in chapter 4, 5, 6 and 7.

Chapter 4 develops and introduces a novel framework for investigating consumers' evaluation of new food technologies, using the example of 3D food printer. The new framework is based on the most often used and significant factors identified in the systematic review investigated in chapter 2. In addition, from a theoretical perspective, chapter 4 compares the novel framework to the Theory of Planned Behavior – a well-established theory and in the context of consumers' new food technology evaluation frequently applied (chapter 2) – in order to determine the performance of both frameworks. Further, from an empirical perspective, chapter 4 compares the results of consumers' evaluation toward 3D-printed food with previous results of consumers' evaluation toward other new food technologies as derived in chapter 2 and chapter 3.

Chapter 5 extends the research on consumers level of chapter 4 with a focus on health-enhancing food products. This study explores the level of involvement of dietary supplements as compared to ordinary food products. Further, the study analyses which factors are influencing consumers' involvement. In the context of making the final purchase decision, involvement is one of the most often used factor to explain consumers' behavior. In chapter 4, involvement is used as a consumers' characteristic variable (food involvement scale by Bell & Marshall (2003)), while chapter 5 investigates purchasing decision by adapting the involvement scale developed by Mittal (1989a).

Chapter 6 extends the analysis to traders' evaluation of new food technologies, which uses the case of improved tomato packaging. This study presents results of an on-station trial to

test the effectiveness of lining material in wooden crates as used in the tomato supply chain in Tanzania. In addition, this chapter assesses how traders perceive postharvest handling practices with wooden crates combined with lining material, especially in terms of perceived net benefits of the improved packaging. The economic dimension of traders' evaluation is also connected to chapter 3.

Chapter 7 supplements traders' evaluation research of new postharvest handling technology in chapter 6. In this study, traders' evaluation is investigated by analyzing a combined model of the Technology Acceptance Model (Davis, 1986) and the Theory of Planned Behavior in order to determine the socio-psychological factors that influence the adoption behavior of traders on an improved tomato packaging. The application of these theories is connected to the results of chapter 2.

Chapter 8 answers the research questions and highlights theoretical, methodological and empirical contributions of the thesis. It also presents implications of the study practice and policy. The thesis concludes with limitations and possible directions for future research in the domain of chain actors' new food technology evaluation.

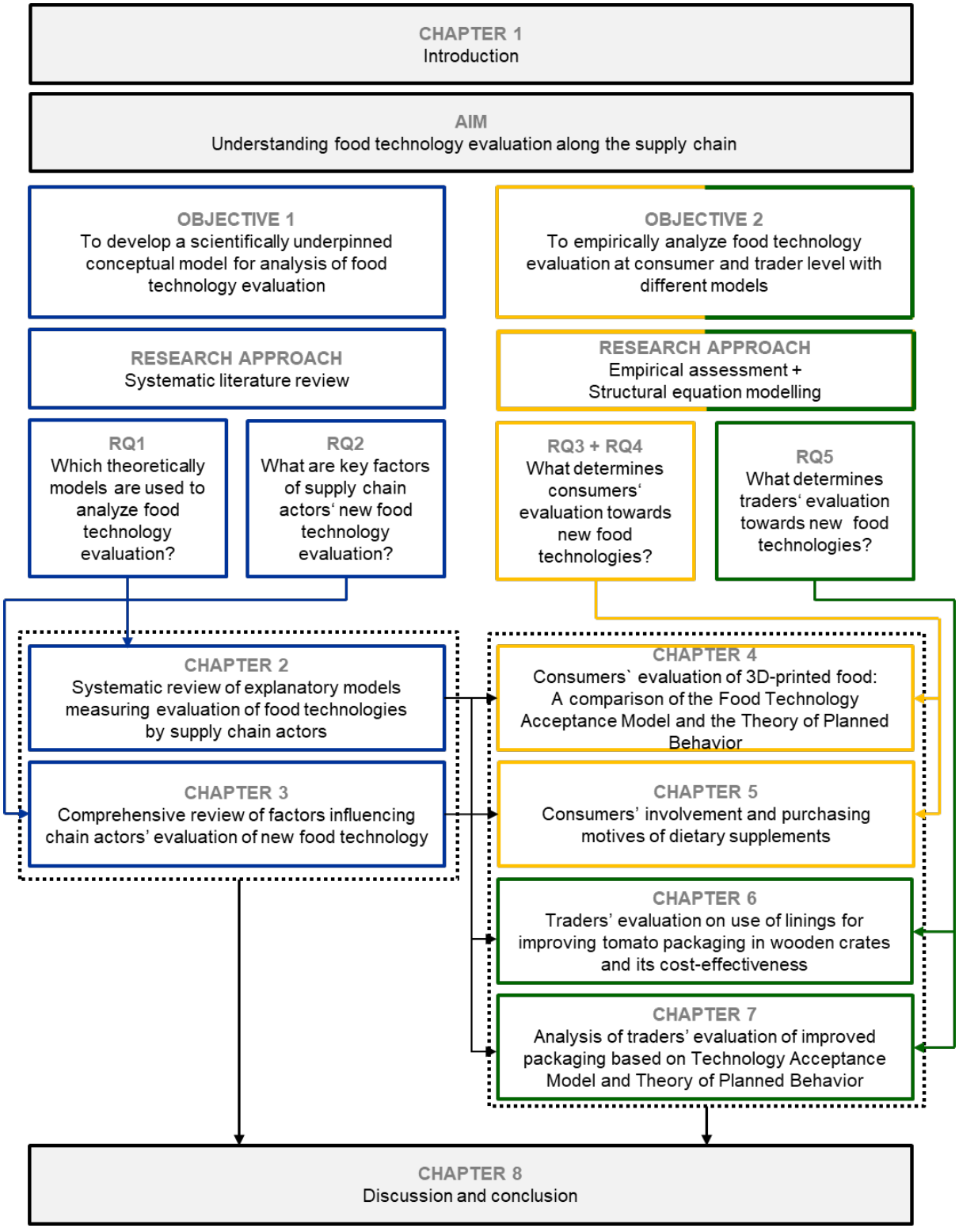

Figure 1.6: Structure of the thesis.

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Part II: Literature reviews

2 Systematic review of explanatory models measuring evaluation of food technologies by supply chain actors

Chapter 2 answers Research Question 1 and its respective sub-questions:

RQ 1: Which theoretically models are used to analyze food technology evaluation?

RQ 1.1: What types of existing food technologies are commonly applied in model based evaluation studies?

RQ 1.2: What levels of the food supply chain are targeted in model based food technology evaluation studies?

RQ 1.3: What well-established theoretical models haven been used to examine food technology evaluation behavior along the supply chain?

This chapter is based on the following publication:

Kamrath, C.; Wesana, J.; De Steur, H.; Gellynck, X.; Bröring, S. (under review): Evaluation of food technologies across supply chain actors – A systematic review of explanatory models. *Submitted to: International Journal of Innovation and Sustainable Development.*

2.1 Introduction

Subsequent to chapter 1, novel food technologies provide opportunities to mitigate current societal challenges, such as food security and food safety, as well as to scale up the circular economy, e.g. through valorizing by-products to derive functional ingredients (Floros et al., 2010). At the same time, consumers and the society at large are more and more neophobic toward food (technologies) (Bearth & Siegrist, 2016; Costa & Jongen, 2006; Frewer et al., 2011; Ronteltap et al., 2007; Siegrist, 2008), which increased the risk of market failures, especially for radical food innovations (Costa & Jongen, 2006; Grunert et al., 1997). However, as food innovations need to be implemented first at the input level of the food industry (farmers and processors) (Bigliardi & Galati, 2013; Hellström, 2003), the ultimate success of an innovation depends on whether it is adopted along the food supply chain (Bigliardi & Galati, 2013; Bröring, 2008; Grunert et al., 2005). In other words, evidence of chain actors' evaluation of food innovations is needed in order to have a holistic understanding of their potential.

Although there is a broad spectrum of literature reviews on food technology evaluation, there are observable shortcomings that future studies ought to address. A primary concern is the scope used while conducting these reviews. When looking at existing reviews, only the consumer has been considered for identifying evaluation studies. This bias toward consumers has also been pointed out by Ronteltap et al. (2007), who suggest exploring acceptance along the whole food supply chain. Moreover, these studies are often limited to a specific food technology. While most reviews looked at GM technology, either through measuring consumers' evaluation of GM foods (Bredahl et al., 1998; Frewer et al., 2013; Hess et al., 2016) or eliciting their willingness-to-pay (Costa-Font et al., 2008; Dannenberg, 2009; De Steur et al., 2014; De Steur et al., 2017b; De Steur et al., 2017c; Lusk et al., 2005), other reviews targeted consumer evaluation of other technologies, such as nutrigenomics (Ronteltap et al., 2007), nutritious foods (including GM and non-GM biofortification) (Mogendi et al., 2016b) and High Pressure Processing (HPP) and Pulsed Electric Fields (PEF) (Olsen et al., 2010). Only few reviews have extended their approach by including several novel food technologies (Frewer et al., 2016; Rollin et al., 2011), others were unspecific of the nature of novel food technologies they investigated (Bearth & Siegrist, 2016; Lusk et al., 2014) or focused on functional foods (Kaur & Singh, 2017; Siró et al., 2008). This creates a knowledge gap for examining the current state of research on evaluation of different applications of food technology, by using the supply side of the food industry.

Second, only one review study made an attempt to aggregate evidence on explanatory models for evaluation of food technologies, using GM foods as a case (Bredahl et al., 1998). Since the last two decades, other reviews have developed their own case-specific models by synthesizing factors used in primary studies. Although explanatory models have made an

attempt to conceptualize and analyze the dynamics of food technology evaluation (Costa-Font et al., 2008), it is striking that no review has taken this under consideration since the work of Bredahl et al. (1998).

Third, the majority of those review studies did not apply the recommended methodology and academic rigor of a systematic review, hence could have missed relevant information needed to make reliable conclusions. Only few reviews on consumers' food technology evaluation have systematically analyzed the literature (Bearth & Siegrist, 2016; De Steur et al., 2017c; Frewer et al., 2013; Frewer et al., 2016; Kaur & Singh, 2017; Mogendi et al., 2016b).

This chapter aims to conduct a systematic review that addresses the above knowledge gaps on technology evaluation by (1) extending the focus beyond consumers to the entire supply chain, (2) targeting a wide range of novel foods and technologies, and (3) examining the use of explanatory models. Due to the latter, the review in this chapter will target studies who used a model based study approach in order to analyze food technology evaluation. The following research questions are investigated:

- What types of existing food technologies are commonly applied in model based evaluation studies?
- What levels of the food supply chain are targeted in model based food technology evaluation studies?
- What well-established theoretical models have been used to examine food technology evaluation behavior along the supply chain?

2.2 Methodology

2.2.1 Search strategy and identification of primary studies

A systematic literature review of published evidence on supply chain actors' evaluation of novel food technologies was undertaken by following the methodological approach of Petticrew & Roberts (2006). The following search syntax was developed and was entered in one electronic database (ISI Web of Science), hence only restricting the search to international peer-reviewed and indexed studies:

> "food tech*" OR "agri-food tech*" OR "food innovation" OR "food process*" OR "food approaches" OR "nutrigenomics" OR "nano-tech*" OR "pulsed electric field" OR "PEF" OR "HPP" OR "high hydrostatic pressure" OR "HHP" OR "high pressure" OR "radio-frequency pasteurization" OR "ultraviolet light" OR "irradiat*" OR "novel food" OR "non-

conventional food" OR "innovative food" OR "altered food" OR "functional food" OR "nutraceuticals" OR "fortif*" OR "enriched food" OR "biofortif*" OR "bio-fortif*" OR "bioeng*" OR "biotech*" OR "agro-biotech*" OR "GM food" OR "gm" OR "gmo" OR "genetic modification" OR "transgene*" OR "cisgene*" OR "clon*"

AND "accepta*" OR "adopt*" OR "attitud*" OR "opinio*" OR "percept*" OR "valuation" OR "willingness" OR "WTP" OR "willingness-to-pay" OR "willingness-to-accept" OR "WTA" OR "willingness-to-try" OR "preference"

AND "consumer*" OR "public" OR "social" OR "citizen" OR "farmer*" OR "processor*" OR "retail*" OR "stakeholder*" OR "supply chain*".

Thereby, search terms that refer to a specific food technology are based on the rational that the technology in question is of empirical relevance and topical. The targeted actors 'farmer', 'processor', 'retailer' and 'consumer' were included as search terms given that they are considered the main actors in the food supply chain (Bigliardi & Galati, 2013). The search syntax was developed in close consultation with other researchers' experiences with systematic reviews and was tested for its robustness.

2.2.2 Definition of screening criteria and screening of primary studies

The extant literature was screened to obtain a comprehensive dataset that is relevant to examine the main research questions in this chapter. For a study to be included in this review, all screening criteria presented in Figure 2.1 had to be fulfilled. Given the focus on analysis of food technologies, new food technologies was defined as a production process that gives "rise to significant changes in the composition or structure of the foods or food ingredients which affect their nutritional value, metabolism or level of undesirable substances" (European Commission, 1997, Article 1). Thus, other technologies applied in the food sector that do not cause significant changes in food, such as novel approaches of packaging, were not considered for inclusion. With respect to the explanatory models used, studies were only included if their models were based on a theory that is widely applied (or refined) through empirical literature. Here, these models are referred to as well-established theoretical models, i.e. a model that is based on fundamental theories (for an overview of behavioral theories and models see Darnton, 2008). For the sake of comparison, articles using a study-specific model were also categorized. Nevertheless, the latter were not used for deeper analysis of findings in this chapter, but are further investigated in chapter 3.

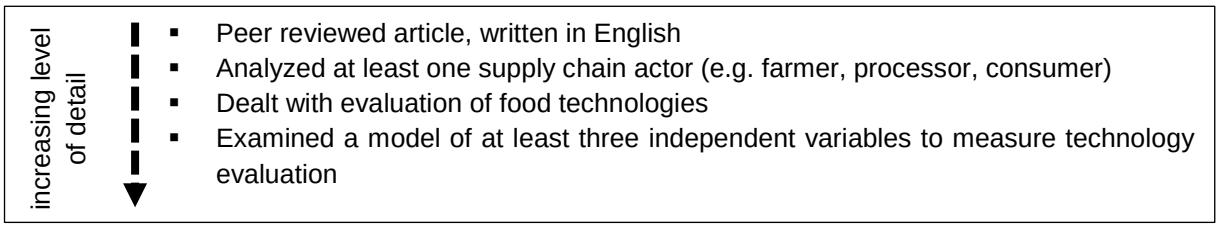

Figure 2.1: Inclusion criteria for systematic review.
Source: Own illustration.

EndNote Web was used as a working database for sorting included and excluded studies based on the aforementioned criteria. The four screening steps included in this review are shown in Figure 2.2. First, doubles were removed before title and abstract screening. Second, titles that did not fit in the scope of the review were removed and those that remained were subjected to an abstract screening. Third, a full-text review was performed to retain articles that applied an explanatory model for evaluation behavior toward novel food technology among one or more groups of supply chain actors. This was the basis for final eligibility and data extraction. Some studies included more than one stakeholder, but treated the whole study as a consumer study as the share of non-consumer stakeholder was small or negligible. Therefore, those studies were considered as consumer oriented studies.

This whole process was performed by two researchers who cross-checked each other to ensure that no study is incorrectly in- or excluded while fulfilling the inclusion criteria. A third party was consulted whenever consensus could not be reached.

2.2.3 Data extraction process

Pre-defined, literature-based and emerging categories were used to develop a data extraction sheet in Excel. In correspondence to the aforementioned research questions, the following study characteristics were extracted: the type of food technology, the targeted supply chain actor, data collection characteristics (method, location, sample) and model characteristics (type of model, constructs included). The final database represents a comprehensive overview of primary studies that used a well-established theoretical model to examine food technology evaluation of a supply chain actor. Given the diversity of methods and measures to examine food technology evaluation, it was not possible to extract a common parameter across studies needed for conducting a meta-analysis.

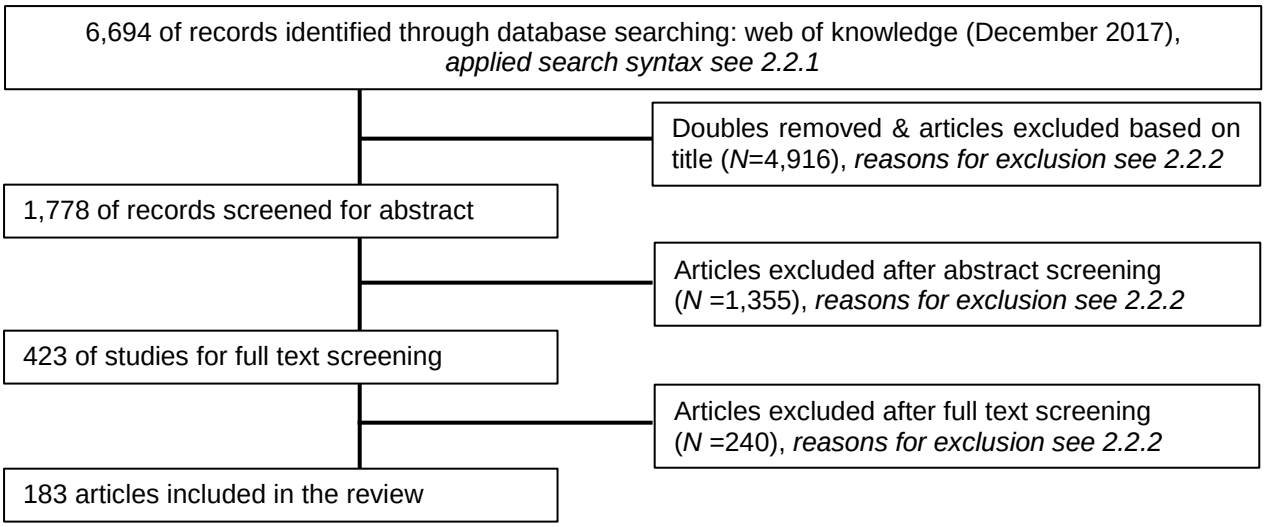

Figure 2.2: Flow diagram of studies selected for review.

Source: Own illustration.

2.3 Results of the review

2.3.1 Main study characteristics

The database search and screening process resulted in 183 relevant papers that were selected for subsequent data extraction. Due to the screening criterion to include only studies applying models with at least 3 independent variables (Figure 2.1), the sample mainly consists of quantitative studies (95%). Thereby, 76% of all selected studies conducted online, face-to-face, postal, or telephone interviews, 13% applied experimental designs (e.g. willingness to pay auctions and choice experiments), and 6% carried out qualitative approaches such as means-end chain laddering techniques or in-depth interviews. The remaining 5% of the studies used secondary data, all of them based on the Eurobarometer[5] (European Commission, 2018b).

With respect to region, most studies were conducted in developed countries (75%), while only 25% target developing countries. Europe covered 45% of the selected studies, as compared to America (South 3%, North 19%) and Asia (18%), Africa (9%, mainly from East Africa) and Oceania (6%). Due to the screening criterion to include only studies applying models with at least 3 independent variables (Figure 2.1), the sample mainly consists of quantitative studies (94%).

[5] Used data: Eurobarometer 52.1 analyzed by Simon (2010); Gaskell et al. (2004); Costa-Font & Mossialos (2005); Eurobarometer 58.0 analyzed by Olofsson et al. (2006); Costa-Font & Gil (2008); Costa-Font & Gil (2009); Eurobarometer 73.1 analyzed by Hudson et al. (2015); Kim & Kim (2015).

2.3.2 Targeted technology and supply chain actor

The number of publications over time highlights an increase of food technology evaluation studies after 2003 (Figure 2.3). This is especially the case for GM food literature, which had a peak in 2008, partially due to the EU moratorium on GM crops (Leibovitch, 2008). Figure 2.4 classifies the number of studies (in relative numbers) according to the targeted food technology, the applied model (discussed in section 2.3.3), and the targeted supply chain actor. While most studies examined GM foods (62%), only 3% of studies targeted non-GM biofortified food (i.e. produced through conventional breeding or agronomic practices). Fortified foods, food enriched with health ingredients or additives, were investigated in 23% of the studies. Processing technologies, like nanotechnology, irradiation or high pressure processing, were selected as a case in 12% of the studies.

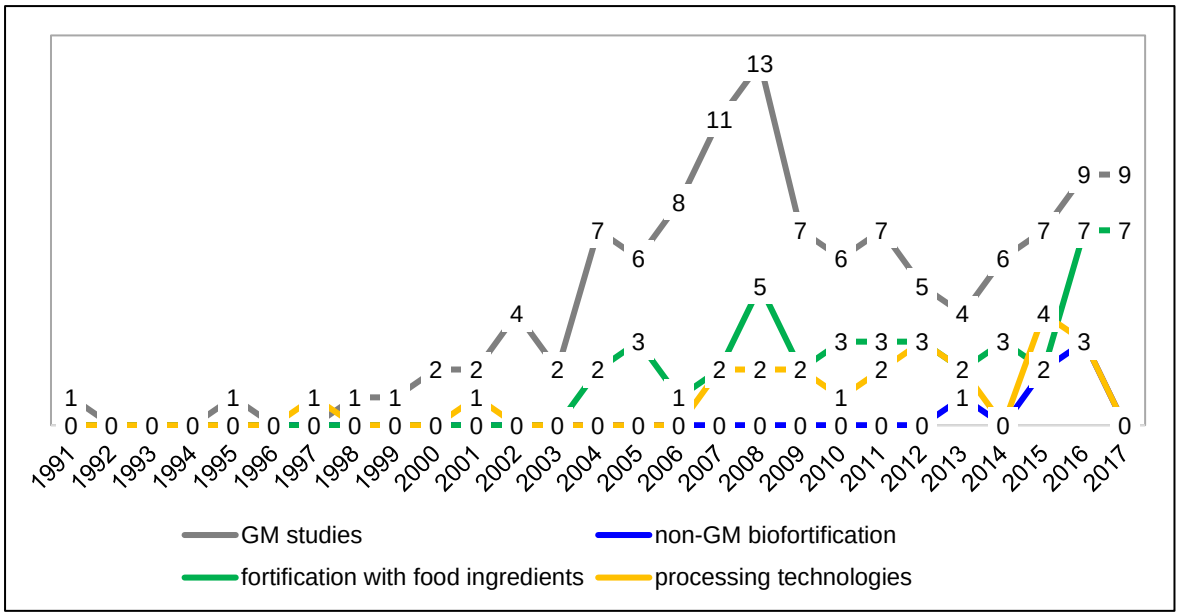

Figure 2.3: Publications on different food technology innovations.

Remark: Numbers are total numbers of papers.

Source: Own illustration.

Regarding the supply chain actors, the majority focused on consumers (92%), while relatively few dealt with farmers and producers (7%) and only two studies included processors (1%). None of the studies specifically looked at retailers.

When the targeted actors were compared against the selected technology, farmer studies solely focused on genetic modification, and were, given their position in the supply chain, not involved in research on food processing technologies or functional foods. Consumers also participated in studies on biofortified food and food additives, though to a lesser extent

compared to GM food. Furthermore, the consumer studies that scrutinized processing technologies mainly looked at nanotechnology approaches. From this follows that the stage of the supply chain where the technology is introduced, will determine which chain actors are selected in research on new food technology evaluation (see also Figure 1.2).

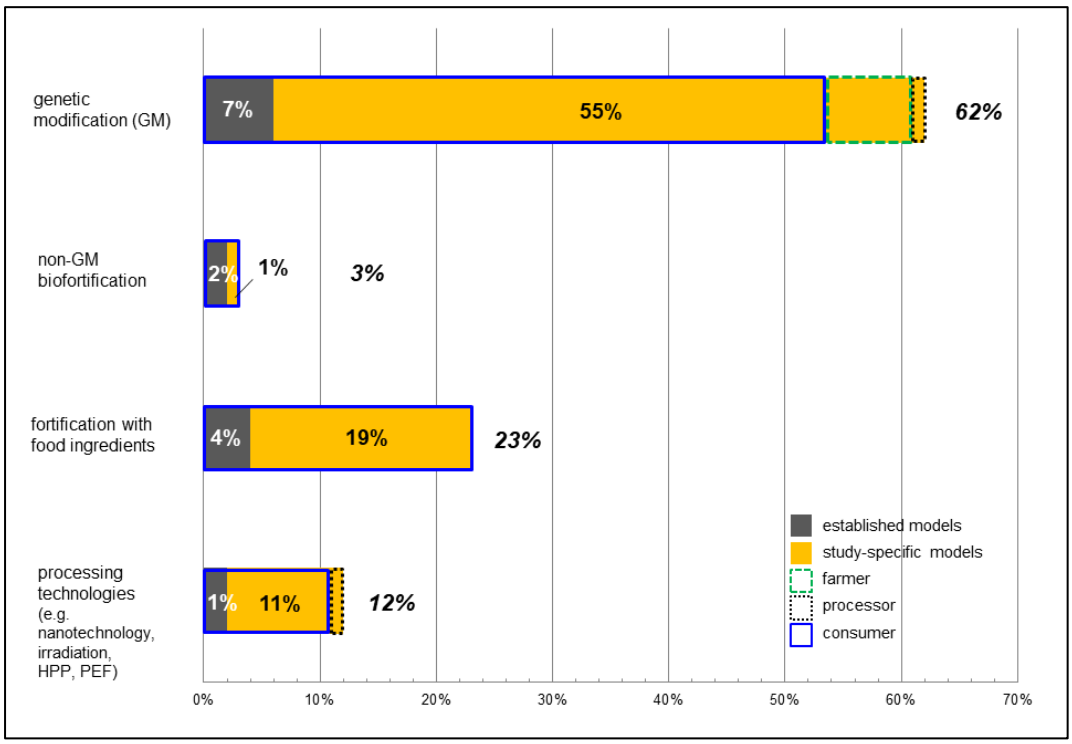

Figure 2.4: Studies according to type of innovation, supply chain actor and applied model.

Remark: Established models are models based on well-known theory; study-specific models are models with particular relationships; retailer is not included due to lack of studies.

Source: Own illustration.

2.3.3 Explanatory models applied for analyzing consumers' food technology evaluation

Only a small share of the sample has applied a well-established theoretical model. These studies were all oriented toward the consumer (26 studies) with exception of 1 study at farmer level and drew upon well-known behavioral models: i.e. the Attitude Model (3 studies), the Theory of Reasoned Action (3 studies) and of Planned Behavior (10 consumer studies, 1 farmer study), the Protection Motivation Theory (9 studies) (Table 2.1) as well as the Health Belief Model (2 studies). An detailed overview of the applied models in the context of the different food technologies is provided in the Appendix (Appendix A and E).

It is important to indicate that 156 other studies (of which respectively 13, 2 and 131 studies at farmer, processor and consumer level) have developed an own explanatory model. This points out a growing tendency to go beyond existing, theory-driven established models (see also Figure 2.5), but perhaps at the drawback of external validity, since models in singular use do not allow for comparison of results.

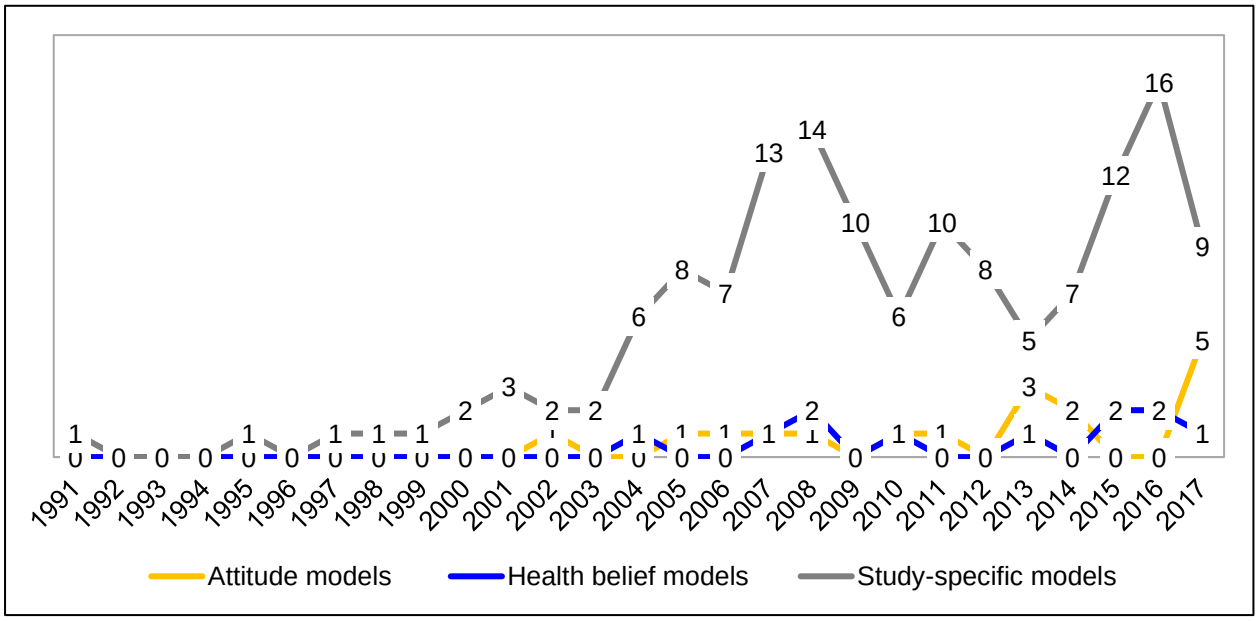

Figure 2.5: Publication timeline with focus on applied models.

Remark: Numbers are total numbers of papers.

Source: Own illustration.

Given the scope of this review, the remainder of this section will provide a detailed narrative synthesis of the 27 studies that have applied a well-established theoretical model. Their characteristics in terms of the type of technology, study characteristics, model name and variables as well as the method of data analysis are described in Table 2.1.

Table 2.1: Models applied for food technology evaluation at farmer and consumer level.

Author	Type of techn.	Study charact.	Model data			Method of data analysis
		Study location and sample size	Model name	Latent variables	Dependent variable	
Farmer						
Oparinde et al. (2017)	Bio-technology/ GM	Nigeria; *N*=288	TPB	• Behavioral belief (+) • Subjective norm (+) • Control belief (+)	Intention to cultivate	OLS regression

Author	Type of techn.	Study charact.	Model data			Method of data analysis
		Study location and sample size	Model name	Latent variables	Dependent variable	
Consumer						
Chen (2008)	Bio-technology/ GM	Taiwan; *N*=564	Attitude Model merged with TPB	• Attitude to technology° • Attitude to nature° • Food neophobia° • Alienation from the marketplace° • Perceived knowledge° • Perceived benefits from GM foods° • Perceived risks from GM foods° • Attitude to GM foods° • Attitude to purchase GM foods (+) • Subjective norm (+) • Perceived behavioral control (ns)	Intention to purchase GM foods	Structural Equation Model
Rodriguez et al. (2013)	Bio-technology/ GM	Spain; *N*=448	Attitude model	• Attitude toward GM food (+) • Perceived benefit of GM food° • Perceived risk from GM food° • Attitude toward GM technology° • Attitude to food safety° • Trust in institutions°	Purchase intention	Structural Equation Modeling
Rodríguez and Salazar (2013)	Bio-technology/ GM	Spain; *N*=448	Attitude model	• Perceived benefits (+) • Perceived risks (-) • Knowledge (ns) • Attittude to GM technology° • Trust in institutions°	Purchase intention	Structural Equation Modeling
Mulder et al. (2014)	Bio-technology/ GM	Netherlands; *N*=579	adapted from TRA + diffusion model	• Knowledge° • Attitude (+) • Injunctive norm° • Descriptive [social] norm (+) • Innovator characteristics° • Risk perceptions°	Intention to use	Structural Equation Modeling
Rezai et al. (2017)	Functional Food/ natural functional food	Malaysia; *N*=2004	TRA + Health Belief Model	• Perceived susceptibility (ns) • Perceived benefits (+) • Perceived barriers (-) • Attitude (+) • Cue to action/subjective norm (+)	Purchase intention	Structural Equation Modeling
Tsai et al. (2010)	Functional Food / nutra-ceuticals	Taiwan; *N*=500	TRA	• Trust belief (ns) • Attitude (+) • Subjective norm (+) • Salesperson's expertise (+)	Intention to purchase	Structural Equation Modeling
Chen (2017)	Functional Food	Taiwan; *N*=487	TPB	• Attitude toward consuming FF (-) • Subjective norm (ns) • Perceived behavioral control (+) • Attention to foods with additives° • Perceived credibility of information° • Perceived risk (+)	Behavioral intention	Structural Equation Model

Author	Type of techn.	Study charact.	Model data			Method of data analysis
		Study location and sample size	Model name	Latent variables	Dependent variable	
Cook and Fair-weather (2007)	Nano-technology	New Zealand; *N*=565	adaptation of TPB	• Attitude tow performing behavior (+) • Subjective norm (+) • Perceived behavioral control (ns) • Self-identity (-)	Behavioral intention	Linear Regression
Cook et al. (2002)	Bio-technology/ GM	New Zealand; *N*=266	adaptation of TPB	• Attitude (+) • Subjective norm (+) • Perceived behavioral control (+) • Self-identity (+)	Intention	Orderet Logit Model
Ghoochani et al. (2017)	Bio-technology/ GM	Iran; *N*=108	TPB	• Attitude toward GMOs (+) • Subjective norm (+) • Perceived behavioral control (ns) • Knowledge° • Benefit (ns) • Risk (ns) • Trust (+) • Ethics (ns)	Behavioral intention	Structural Equation Model
Kim et al. (2014)	Bio-technology/ GM	South Korea; *N*=387	TPB	• Ecological concern (-) • Attitude (+) • Subjective norm (+) • Perceived behavioral control (-) • FTNS-Questions°	Behavioral intention	Structural Equation Modeling
Lu, Gursoy (2016)	Bio-technology/ GM	USA; *N*=220	TPB	• Attitude toward GM foods (-) • Subjective norm (+) • Perceived behavioral control (+) • Social trust° • Consideration of future consequences (ns)	Purchase intention	Structural model
Patch et al. (2005)	Functional Food/omega -3 fatty acide	Australia; *N*=42	TPB	• Attitude toward eating enriched product (+) • Belief strength toward purchasing novel foods° • Subjective Norm (ns) • Normative belief° • Motivation to comply° • Perceived behavior control (ns)	Intention	Linear Regression
Prati et al. (2011)	Bio-technology/ GM	Italy; *N*=1009	TPB	• Subjective norm (+) • Perceived control (-) • Attitude (+) • Perceive risk (ns) • Perceived benefit (+)	Intention to consume GM	Structural Equation Modeling
Spence and Townsend (2006)	Bio-technology/ GM	UK; *N*=99	TPB	• Attitude toward GM food (+) • Subjective norm (ns) • Peceived Behavioral control(-) • Moral norms (ns) • Self-identity (+) • Emotional Involvement (+)	Intention to buy	Linear Regression
Talsma et al. (2013)	Non GM bio-fortification/ Pro-Vitamin A	Kenya; *N*=150	TPB	• Health behavior identity (+) • Attitude toward behavior (ns) • Perceived barriers (-) • Subjective norms (ns) • External control beliefs (-) • Cues to action (+) • Knowledge° • Perceived susceptibility° • Perceived severity° • Health value°	Intention	Multiple Regression

Author	Type of techn.	Study charact.	Model data			Method of data analysis
		Study location and sample size	Model name	Latent variables	Dependent variable	
Cox and Bastiaans (2007)	Functional Food / selenium enriched foods	Australia; *N*=212	PMT	• Severity (S) (+) • Vulnerability (V) (+) • Product-efficacy (PE) (+) • Self-efficacy (SE) (+)	Importance of protecting myself against the risk of cancer	Multiple Regression Analysis
Cox et al. (2008)* * here only summary of variables presented	Biotechnology/ GM	Australia; *N*=220 (milk and bread consumer)	extended PMT	• Behavior (product) efficacy° • Self-efficacy (different products) (+) • Perceived severity of CHD° • Perceived vulnerability to CHD° • Belief that GM oilseed is unnatural(+) • Belief that fishmeal is unnatural° • Perceived risk/benefit of GM oilseed° • Perceived risk/benefit of fishmeal°	Likelihood to purchase farmed fish or product with fish oil or with GM oilseed	Multiple Regression Analysis
Cox et al. (2004)	Functional Food	Australia; *N*=290 (age between 40-60)	adaptation of PMT	• Self-efficacy (+) • Efficacy (+) • Severity (+) • Importance of vulnerability (+) • General vulnerability (+) • Importance others vulnerability (+) • Inevitable (+)	Intention to naturalness, sweetener, effectiveness of genetic modification or supplements	Multiple Regression Analysis
Crowley et al. (2013)	Irradiation	North America-USA; *N*=478	adaptation of PMT	• Perceived safety of meat irradiation (+) • Perceived relative severity (-) • Fears associated with. meat Irradiation (-)	Likelihood of eating irradiated meat	Structural Equation Modeling
De Steur, Mogendi et al. (2015)	Non GM bio-fortification/ iodine	Africa-Uganda; *N*=400 (1st sample *N*=360 are parents and 2nd sample *N*=40 are school heads of primary school)	PMT	• Perceived fear (ns) • Perceived vulnerability (ns) • Perceived severity (ns) • Response efficacy (ns) • Self-efficacy (+) • Response cost (-) • Academic performance satisfaction (ns) • Knowledge about iodine and iodine Deficiency Disorders (ns)	Intention to adopt biofortified foods	Multiple Regression Analysis
Henson et al. (2008)	Functional Food / lycopene	North America-Canada; *N*=268 (male, primary food purchaser in housheold)	PMT	• Fear (+) • Own health status (-) • Vulnerability of close others (+) • Relative risk (ns) • Severity (ns) • Inevitability (ns) • Response efficacy (+) • Knowledge (-) • Self-efficacy (+)	Intention to buy FF or nutraceutical	Probit Regression
Henson et al. (2010)	Functional Food / phytosterols	North America-Canada; *N*=446	PMT	• Severity (+) • Vulnerability (+) • Cholesterol risk (+) • Response efficacy (+) • Self-efficacy (+)	Behavioral intention	Structural Equation Modeling

Author	Type of techn.	Study charact.	Model data			Method of data analysis
		Study location and sample size	Model name	Latent variables	Dependent variable	
Mogendi et al. (2016c)	Non GM bio-fortification/ iodine	Africa-Kenya, Tanzania, Uganda; *N*=1200 (1st sample *N*=1080 households/ parents and 2nd sample *N*=120 schools heads)	PMT	• Severity (+/-) • Vulnerability (+/-) • Fear (+/-) • Response efficacy (+/-) • Response cost (+/-) • Self-efficacy (ns) • Protection motivation (behavioral intention) (+/-) • Satisfaction level (ns) • Knowledge (ns/-) • Information (ns)	WTP at premium or at discount level	Tobit Regression
Mogendi et al. (2016a)	Non GM bio-fortification/ iodine	Africa-Kenya, Tanzania, Uganda; *N*=1080 households/	PMT (consumer)+ TAM (farmer)	• Protection motivation (behavioral intention) (+) • Perceived Severity (+) • Perceived vulnerability (ns) • Perceived fear (+) • Response efficacy (+) • Response cost (ns) • Self-efficacy (ns)	WTP at premium or at discount level	Structural Equation Modeling
Vlontzos, Duquenne (2016)	Bio-technology/ GM	Greece; *N*=1461	Health Belief Model	• Behavioral intention (-) • Severity (ns) • Nutritional confidence (ns) • Barriers (+) • Susceptibility (ns) • Health benefits (ns)	WTP for GM foods	Logistic regression model

Remarks: (+) positive-, (-) negative significant or (ns) non-significant relationship between independent and dependent variable; or relationship ° not tested. TRA= Theory of Reasoned Action. TPB = Theory of Planned Behavior. PMT=Protection Motivation Theory. WTP=Willingness to Pay.

Source: Own illustration.

2.3.3.1 Attitude models at consumer level

The attitude-based theory was used in 18 studies, in specific 3 studies applied the Attitude Model, 3 studies the Theory of Reasoned Action and 11 studies the Theory of Planned Behavior.

Attitude Models (AM) – The multi-attribute attitude model by Fishbein (1963) measures individual's attitude toward an object as a function of his beliefs about the object and the evaluative aspects of those beliefs and is later analyzed as predictor for behavioral intention (i.e. willingness to perform the behavior) (Fishbein & Ajzen, 1975). Within the focus on technology evaluation, the AM was applied for GM food evaluation in Europe (Rodríguez-Entrena et al., 2013; Rodríguez-Entrena & Salazar-Ordóñez, 2013) and Eastern Asia (Chen, 2008). Studies used different attitude applications in order to describe the behavioral intention, e.g. attitude toward GM food, GM technology and food safety (Rodríguez-Entrena et al., 2013) derived from the object in focus. Furthermore, perceived benefits and perceived risks are also associated with attitude (Chen, 2008; Rodríguez-Entrena & Salazar-Ordóñez, 2013).

Theory of Reasoned Action (TRA) – Attitude (i.e. feeling of favorableness toward the food technology) and subjective norm (i.e. support of important others toward implementing or consuming the food technology) are two key concepts from the TRA used as predictors of behavioral intention (Fishbein & Ajzen, 1975). Three studies applied TRA in the context of GM and fortified food in Europe (Mulder et al., 2014) and Eastern Asia (Rezai et al., 2017; Tsai et al., 2010). Tsai et al. (2010) shows that both consumer attitude, subjective norm and salesperson's expertise enhance the intention to purchase nutraceuticals. Moreover in the context of functional food, the study by Rezai et al. (2017) results in a positive relationship of attitude and subjective norm to consumers' intention to purchase natural functional food while combining the TRA with the Health Belief Model. In addition, Mulder et al. (2014) applied the same theory in the context of biotechnology (i.e. in vitro meat), but expanded the theory by including "innovativeness" (i.e. being the first adopting new ideas or inventions) as a variable adapted from the diffusion of innovation theory. Thereby, the attitude construct as well as the subjective norm positively influenced purchase intention that was further indirectly influenced by the innovator characteristics.

Theory of Planned Behavior (TPB) – This theory is extensively used to explain human behavior that behavioral attitude, subjective norm and perceived behavioral control (i.e. the perceived ability to identify or consume a novel food) affect behavioral intention (i.e. willingness to perform the behavior), which in turn affects the actual behavior (Ajzen, 1991). The majority of the studies that used an attitudinal model applied TPB (11 studies) but in different contexts. TPB was the only well-established theoretical model that was also applied at farmer level. Oparinde et al. (2017) used the TPB in order to analyze farmers' intention to cultivate provitamin A GM cassava in Nigeria. On the other hand 10 studies focused on consumers, thereby 3 studies targeted Oceania as well as Asia, 2 studies were conducted in Europe and only 1 study focused Northern America and Eastern Africa, respectively. Most studies applied their TPB models to GM food (Cook et al., 2002; Ghoochani et al., 2017; Kim et al., 2014; Lu & Gursoy, 2016; Prati et al., 2012; Spence & Townsend, 2006), while 2 studies analyzed technology evaluation toward functional foods (Chen, 2017; Patch et al., 2005), and only 1 study focused on non-GM biofortification (Talsma et al., 2013) and processing technology (Cook & Fairweather, 2007), respectively. On a more detailed level, results indicate that a positive attitude toward technology or behavior (purchase or eating the novel food) has a positive and significant association with a specified behavioral intention (Chen, 2008; Cook et al., 2002; Cook & Fairweather, 2007; Ghoochani et al., 2017; Kim et al., 2014; Patch et al., 2005; Prati et al., 2012; Spence & Townsend, 2006; Tsai et al., 2010), except for 3 studies (Chen, 2017; Lu & Gursoy, 2016; Talsma et al., 2013). In their studies, no significant relationship was found between attitude toward behavior and the behavioral intention. Social

pressure and beliefs by significant others (subjective norm) positively predicted behavioral intention in many cases (Chen, 2008; Cook et al., 2002; Cook & Fairweather, 2007; Ghoochani et al., 2017; Kim et al., 2014; Lu & Gursoy, 2016; Prati et al., 2012) but was non-significant in 4 cases (Chen, 2017; Patch et al., 2005; Spence & Townsend, 2006; Talsma et al., 2013). The observed relationship between perceived behavioral control and behavioral intention is weakest, even non-significant in 4 studies (Chen, 2008; Cook & Fairweather, 2007; Ghoochani et al., 2017; Patch et al., 2005). With regards to GM food, perceived control was found to have a negative effect in 3 studies (Kim et al., 2014; Prati et al., 2012; Spence & Townsend, 2006), whereas the opposite was also observed in 3 studies (Cook et al., 2002; Lu & Gursoy, 2016; Talsma et al., 2013). As stated by Prati et al. (2012), this obvious contradiction may be related to the wording of the items used to measure this construct as 3 studies linked perceived control to purchasing GM food (Cook et al., 2002; Lu & Gursoy, 2016; Talsma et al., 2013), whilst 3 other studies measured control over avoiding GM food (Kim et al., 2014; Prati et al., 2012; Spence & Townsend, 2006). In the one example of TPB at farmer level, attitude, subjective norm and control belief had a significant positive influence on farmers' intention to cultivate GM cassava.

2.3.3.2 Health Belief Models at consumer level

Models in accordance with health behavior theory were used in 11 studies, i.e. the Protection Motivation Theory (9 studies) and the Health Belief Model (2 studies) – all at consumer level.

Protection Motivation Theory (PMT) – This theory is the second most applied theory to examine consumers (9 studies). This theory explains how the cognitive process of threat appraisal interacts with coping appraisal to generate an intention to adopt a recommended preventive health behavior (Maddux & Rogers, 1983). Threat appraisal estimates the arousal of fear for respondents to perceived seriousness of a depicted event (severity) and considers the susceptibility to the threat (vulnerability) (Neuwirth et al., 2000; Prentice-Dunn & Rogers, 1986; Rogers, 1975). Coping appraisal consists of one's belief that a given behavior will or will not cope with the threat (response efficacy) and one's belief about being able to successfully perform the requisite health preventive behavior (self-efficacy) as well as the estimation of the costs involved in the execution of the health behavior (response cost) (Maddux & Rogers, 1983).

Out of the 9 PMT studies, 3 studies focused North America, Oceania and East Africa, respectively. This theory was not applied in European or Asian countries, where the focus was mainly on AMs (see Table 2). Eight studies focused on either functional (Cox et al., 2004; Cox & Bastiaans, 2007; Henson et al., 2008b; Henson et al., 2010), GM enriched in omega-3 fatty

acids (Cox et al., 2008) or non-GM biofortified iodine-enriched foods (De Steur et al., 2015; Mogendi et al., 2016a; Mogendi et al., 2016c), indicating increasing research interest in foods that positively affect consumer health (FoodDrinkEurope, 2016; see also Figure 2.3 for publication timeline). Only 1 study applied the PMT in the context of processing technologies, i.e. for irradiated food (Crowley et al., 2013).

For threat appraisal, severity and vulnerability were positively associated with protection motivation in seven studies (Cox et al., 2004; Cox et al., 2008; Cox & Bastiaans, 2007; Henson et al., 2008b; Henson et al., 2010; Mogendi et al., 2016a; Mogendi et al., 2016c). Fear was only measured in five studies with positive associations from studies by Henson et al. (2008b) and Mogendi et al. (2016a; 2016c). In a study on irradiated meat by Crowley et al. (2013), negative influences of severity and fear toward the likelihood of eating were observed. This could be explained by the partial and adapted approach of applying PMT, exemplified by variations in questionnaires used for measuring severity and fear as well as the differences between processing technology (irradiation) and health enriching foods. For coping appraisal, the positive relationships with respect to response efficacy and self-efficacy were reported in 6 studies (Cox et al., 2004; Cox et al., 2008; Cox & Bastiaans, 2007; De Steur et al., 2015; Henson et al., 2008b; Henson et al., 2010) while the negative influence of response costs, i.e. estimation of the costs involved in the execution of the health behavior, to the protection motivation is supported by 2 studies (De Steur et al., 2015; Mogendi et al., 2016c). Consistent with Maddux & Rogers (1983), self-efficacy was the most significant predictor of behavioral intention (Cox et al., 2008; Cox & Bastiaans, 2007; De Steur et al., 2015; Henson et al., 2008b; Henson et al., 2010).

Health Belief Model (HBM) – This model is the basis of the PMT and is applied in 2 studies whereby once in combination with the TRA (Rezai et al 2017). In this study, perceived susceptibility (≙vulnerability) had no significant, perceived benefits (≙response efficacy) a positive, and perceived barriers (≙response costs) a negative relationship to consumer intention to purchase natural functional foods in Malaysia. The study by Vlontzos & Duquenne (2016) chose WTP for GM food as a dependent variable that were only positively significant influenced by barriers, all others were non-significant.

2.4 Other applied models along the supply chain

At *farmers*' level in particular, adjusted equation models (i.e. probability or utility functions) (Breustedt et al., 2008; Luh et al., 2014; Useche et al., 2009), a trait-based model (Edmeades & Smale, 2006) and a survival model (Barham et al., 2014) were used. These 'models' are applied with different sets of variables in each research setting without examining other

relationships between independent and dependent variables than to what is done with well-established theoretical models at consumer level.

At *processors'* level, one study developed a model analyzing the influencing factors toward the adoption of product or process innovation in the Canadian food processing industry. Thereby different factors compared to farmers and consumers were used, i.e. impact of innovation (on business through entering international markets or keeping up with competitors) and factors hindering innovation (e.g. lack of information on markets, difficulty finding co-operators) (Brewin et al., 2009). The results of a second study at processor level indicate the positive influences of social acceptance as well as market attractiveness on firms' intention of using GMOs industrially. But the managerial interpretation of the industrial use of GMOs along the opportunity-threat dimension (i.e. whether the industrial use of GMOs will have a positive or a negative impact on firm performance and/or operations) had no significant effect on firms' intention (Sung & Hwang, 2013).

At *consumers'* level with regard to quantitative approaches, other well-established theoretical models are the Classical Diffusion Model (Rogers, 1995) combined with a risk perception theory (Slovic, 1986), Schlenker's accountability model (Schlenker et al., 1994), the Value-Attitude-Behavior hierarchy (VAB) model (Rokeach, 1973; Tudoran et al., 2009), the Regulatory Focus Theory (Higgins, 1997) and the Model of Corporate Social Responsibility (Carroll, 1979). Given that they were only applied once within the included studies, they will not be discussed in detail. While the aforementioned models were used for quantitative data collection, there was one study (Krutulyte et al., 2008) that applied a qualitative approach, i.e. in-depth interviews following the Health Action Process Approach (HAPA), adapted from Schwarzer (1992).

Only one study proposed a combined model of well-established theories with focus on *multiple (two) supply chain actors*, namely farmers and consumers, in a healthy-food supply chain. In their study on potential acceptance of biofortified vegetable legumes in Eastern Africa, Mogendi et al. (2016a) developed the so called PMTAM model that consists of the PMT as well as the Technology Acceptance Model (TAM), of which the former is tested in a consumer study (De Steur et al., 2015; Mogendi et al., 2016c) and the latter in a farmer context (Mogendi, 2016). The TAM, which was originally applied in the field of information technologies and systems (Davis, 1986), assumes that the acceptance of new technology is determined by two key beliefs: perceived usefulness, i.e. the extent to which using a technology will improve productivity and perceived ease of use, i.e. the extent to which using a technology will be free of effort.

2.5 Discussion

This comprehensive systematic literature review in this chapter is considered the first of its kind to assess models applied in the domain of food technology evaluation along the supply chain. This chapter delivers an extensive overview of targeted novel food technologies as well as subsequent application of well-established theoretical models to measure evaluation behavior of different supply chain actors. Further, an exploration of the key determinants gives an indication of the key factors affecting the success of new food technologies.

2.5.1 Findings

The findings indicate that extant research has been primarily devoted to GM foods compared to other food innovations. Consequently, research on biofortified or functional foods and processing technologies (that build upon theoretical models) as well as research in developing countries is limited.

Regarding supply chain actors and use of well-established theoretical models, the results demonstrate that most studies apply study-specific models that focus on consumers. It is striking that only 15% of all included studies use similar approaches based on well-established theoretical models, while the remaining 85% (156 studies) make use of very particular relationships. Indeed, researchers tend to develop their own models with a combination of variables that could be part of well-established theoretical models. The application of different models produces heterogeneous results which makes it difficult to compare and validate findings, within as well as between food technologies and actors. An overview of 60 social-psychological models and theories of behavior provided by Darnton (2008) shows that there is overall a substantial amount of established theories, aside from the large body of research using study-specific models. However, in the context of new food technologies the application of well-established theories is rather rare.

Even though the dominance of consumers as actor was expected, it was very high. Only few studies (based on study-specific models) could be identified at farmer level, while adoption research on processors/retailers is almost lacking. No study with a vertical analysis along the food supply chain, systematically comparing adoption behavior among several actors could be identified. This is a shortcoming as innovation diffusion is more likely to be successful if all supply chain actors initially adopt new technology (Bigliardi & Galati, 2013; Bröring, 2008; Grunert et al., 2005; Hermans et al., 2017) and raises the question how existing models, mainly applied at consumer level, are transferable to other actors who have different interests and concerns. Several actors are mentioned in some studies, but they are usually analyzed

as part of the public and therewith as consumers but the differences between actor groups are not mentioned. There is a current lack of research that uses different models according to the particular supply chain position. One exception is the model proposed by Mogendi et al. (2016a) that assigns well-established theories, like the PMT and TAM to different actors (farmers and consumers). While this approach is interesting, additional research is needed to validate these and other combined models. For example, the TAM and the TPB can effectively be used together, as shown by Mathieson (1991) for information systems, and is assumed to be effective in the context of novel food technology adoption (see also chapter 7) as well.

Although there is limited use of models at the farmer level concerning food technology evaluation, well-established theoretical models have been empirically tested in other contexts (Borges et al., 2019). For example, the TAM has been used to investigate farmer behavior toward adoption of precision agriculture (Adrian et al., 2005; Rezaei-Moghaddam & Salehi, 2010), dairy farming technology adaptation (Flett et al., 2004) and information technology (Aleke et al., 2011). Another example for farmer oriented research is the TPB, which is applied on other food related topics, such as farm diversification (Hansson et al., 2012), adoption of new stress-tolerant rice variety (Yamano et al., 2015), farmers' behavior regarding water conservation (Yazdanpanah et al., 2014) and adoption of GM cassava (Oparinde et al., 2017). Overall, latent variables used in these studies explained significant variations observed in the adoption behavior of farmers, hence showing reasonable predictive validity and the applicability of those theories in the context of farmers' adoption behavior.

Only 2 studies at processor level was identified within this review although the processing industry is affected by the consumer demand for new foods and changes in eating habits (Zink, 1997). This research gap at the level of food processing needs to be filled to understand the adoption behavior along the full supply chain. Processors play a key role in the food supply chain and should be investigated before implementing a novel food technology. Processors' motivation to adopt innovative technologies is primarily assumed to be influenced by economic or strategic factors and can be measured through perceived benefits (i.e. access to market, usability of technology, technologies impact on sustainability criteria) by best applying well-established theoretical models such as the TPB and TAM. This assumption and further influencing factors need to be tested by empirical research.

At consumer level, several well-established theoretical models could be identified; the most common are TRA, TPB (mostly applied to GM) and PMT (applied for functional food and non-GM biofortification). Several other theories exist that are widely applied to analyze consumers' evaluation behavior but hardly in the context of novel food technologies, i.e. the TAM and its extensions such as Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003), Technology Readiness Index (TRI) (Parasuraman, 2000) and

Motivational Model (Vallerand, 1997) applied in the information and communication technology (ICT) literature. In the context of health behavioral, the Social Cognitive Theory (Bandura, 1986) and the Trans-theoretical Model of Change (Prochaska & DiClemente, 2005) are applied, but had limited prediction of health oriented behavior (Baranowski et al., 1999). Other relevant attitude change models are the Elaboration Likelihood model (Petty & Cacioppo, 1986) and the Social Judgment Theory (Sherif & Hovland, 1961). Those theoretical frameworks can be applied in this context or can be combined into a more comprehensive model out of the distinct constructs. In addition, results of qualitative approaches, such as Gutman's means-end chain analysis (1982), can support or replenish quantitative models. Based on the qualitative approaches, grounded theory could generate new concepts particularly to evaluation behavior toward novel food technologies (Betts et al., 2010).

2.5.2 Future research

Beyond the food innovations identified in this systematic review, several new food technologies are developed meanwhile. These may comprise 3D printers, upgrading residual streams and exploiting alternative sources of protein or radical approaches like synthetic biology or CRISPR/Cas. Many new food innovations are purely technology push and call for intensive evaluation research. Therefore, several recommendations based on this systematic literature review are made: generally, it is observed that there is no consensus on the terminologies used in this domain of research. Appropriate use of terminology related to evaluation of food technology requires harmonization of definitions, measurement approaches and use of supply chain actors' evaluation frameworks (Mogendi et al., 2016b). Future research should therefore focus on a greater consistency in use of validated measures that would assist comparability across studies to identify overarching concepts enabling the identification of factors influencing technology evaluation.

Based on the review in this chapter, following steps for future evaluation studies in the field of food technologies are suggested:

- Based on the various methods and models used for analyzing consumer evaluation, a comprehensive synthesis of factors from the food evaluation research domain can result in novel food technology acceptance models at consumers' level. This is similar to the approaches mentioned by Bredahl et al. (1998). [Therefore, see chapter 3.]
- Expand research beyond the consumer level to capture the entire supply chain: As a starting point, studies at the supply side (e.g. farmer, processor) based on well-established theoretical models (e.g. Technology Acceptance Model) are suggested for the purpose of comparison between studies and to test external validity. Thereby,

variables from well-established theoretical models need to be adapted to the specific research context and supply chain actor. [Therefore, see chapter 7.]

- A holistic model for analyzing the whole food supply chain can be developed. For example, one could adapt the Technology, Regulatory and Market Readiness Level Simulation Model based on Kobos et al. (2013) or the Innovation Readiness Level by Jullien (2014). The former assessed the maturity of a given technology as well as the commercial success by providing the political capital and market acceptance criteria (Kobos et al., 2013). The latter combines five readiness levels, these are the Technology Readiness Level, the IP Readiness Level, the Market Readiness Level, the Consumer Readiness Level and the Society Readiness Level (Jullien, 2014). This tool allows assessing the innovation potential of a given technology considering the maturity of those five dimensions, including several supply chain actors (i.a. manufacturers, politics, consumers) but also fosters an alignment between technology push and market pull, to avoid rejection of especially technology driven innovations. [For a starting point, see chapter 4.]

2.6 Conclusion

This chapter systematically reviewed the research landscape on the evaluation of new food technologies, with a particular focus on the models that have been applied. The heterogeneity of those models points out the need to explore novel, or combined theoretical frameworks to allow for comparison of key factors between technologies and across countries. In conclusion, the lack of applied well-established theoretical models was identified, needed for comparing technology evaluation behavior, as well as the lack of a chain approach, a requirement for a comprehensive understanding of evaluation behavior along the food supply chain.

The next chapter seeks to fill these research gaps by systematically identifying factors influencing food technology evaluation by different chain actors. It attempts to provide the most relevant factors for developing a Food Technology Acceptance Model, especially at consumer level (see step A, section 2.5.2). The proposed model based on results of chapter 3 is further applied in chapter 4. Chapter 6 and 7 contribute to the understanding of food technology evaluation at the supply side (see step B, section 2.5.2), e.g. by applying well-established theories, i.e. TPB and TAM, at traders' level.

3 Comprehensive review of factors influencing chain actors' evaluation of new food technology

Chapter 3 answers Research Question 2 and its respective sub-questions:

RQ 2: What are key factors of supply chain actors' new food technology evaluation?

RQ 2.1: What are most often used descriptive and psychological factors within food technology evaluation research?

RQ 2.2: Which factors show significant relationships to one of the indicators of food evaluation?

This chapter is based on the following publication:

Kamrath, C.; Wesana, J.; Bröring, S.; De Steur, H. (2019): What do we know about chain actors' evaluation of new food technologies? A systematic review of consumer and farmer studies. *Comprehensive Reviews in Food Science and Food Safety 18 (3):* 798-816. DOI: 10.1111/1541-4337.12442.

3.1 Introduction

Following the shortcomings in the research of chain actors' food technology evaluation identified in section 2.5.2, this chapter continues the analysis of factors influencing food technology evaluation. To this end, it analyses key actors in the food chain, i.e. farmers, processors, retailers, and consumers (Michalak & Schroeder, 2011). Many researchers have developed explanatory models to obtain a better understanding of consumers' new food technology evaluations. These models were either derived from theories like the Theory of Planned Behavior (Ajzen, 1991) and the Protection Motivation Theory (Rogers, 1975), or were specifically developed for the purpose of a study (Bearth & Siegrist, 2016; Lyndhurst, 2009). In the following the former are called 'well-established theoretical models', while the latter are named 'study-specific models'. Results of chapter 2 have shown that the majority of studies made use of study-specific models (85%), and only 15% of included 183 studies applied well-established theoretical models. A comprehensive analysis of the outcomes of such study-specific models is currently lacking.

Overall, the research gaps can be specified by (1) lack of a comprehensive analysis of factors describing chain actors' new food evaluations, and (2) the lack of the non-consumer perspective. Consequently, this chapter aims to conduct a systematic review of the key factors of supply chain actors' new food technology evaluations in order to contribute to the limited research and knowledge gaps related to this topic. Hence, the following research questions are investigated:

- What are most often used descriptive and psychological factors within food technology evaluation research?
- Which factors show significant relationships to one of the indicators of food evaluation?

Therefore, this chapter (1) synthesizes and analyzes the frequency distribution of included factors and (2) evaluates the significant relationships between factors. The analysis on primary studies is comprehensive in different ways. It systematically analyzes and compares factors that influence chain actors' new food technology evaluation indicators; it includes outcomes from both well-established theoretical and study-specific models; and it goes beyond the findings of consumer-oriented research by including one or more other food supply chain actors, technology-specific, or non-systematic reviews. The outcomes of this chapter aim to contribute to a better understanding of the main factors influencing chain actors' new food technology evaluations, which will be relevant for the conceptualization and measurement of future studies such as the research underlying in chapter 4. This is also of interest for the implementation of future new food technologies along the food supply chain.

3.2 Methodology

3.2.1 Search strategy, identification and screening of primary studies

This chapter makes use of the same database of chapter 2 (see section 2.2). Thus, the search syntax as well as the identification and screening process of primary studies remain the same as in sections 2.2.1 and 2.2.2 presented.

3.2.2 Data extraction

In addition to the extracted factors in chapter 2 (indicated in section 2.2.3), for the database in this chapter the following information from selected studies were extracted: factors influencing technology evaluation, data analysis method, and significant relationships between identified factors and the evaluation concept of interest.

The final database represents a comprehensive overview of articles focusing on the conceptual analysis of evaluation behavior toward different novel food technologies among actors along the food supply chain. As a variety of models and methods were used to measure chain actor evaluation in this research context, it was impossible to extract a common parameter across studies that in addition would suit a meta-analysis. Thus, a systematic review that extracts, checks, and summarizes information on determined methods and identified results was applied.

3.2.3 Procedure of grouping variables

One of the research objectives is to analyze significant relationships between variables that describe chain actors' evaluations of novel food technologies. Therefore, included studies used more or less similar variables with different wordings, e.g. attitude toward technology, opinion about the technology, or technology optimism. The large database, or list of variables, had to be summarized and grouped to broader variables. Therefore, the procedure of qualitative content analysis, widely used for analyzing text data (Hsieh & Shannon, 2005), was adapted to reduce the number of variables. More specific, the conventional content analysis (Hsieh & Shannon, 2005; Schilling, 2006), also described as inductive category development (Mayring, 2000), was applied as this procedure allows the categories and their names to flow from the data instead of using preconceived categories (Hsieh & Shannon, 2005). The procedure of category development out of extracted variables is presented in Figure 3.1 and was carried out by two researchers.

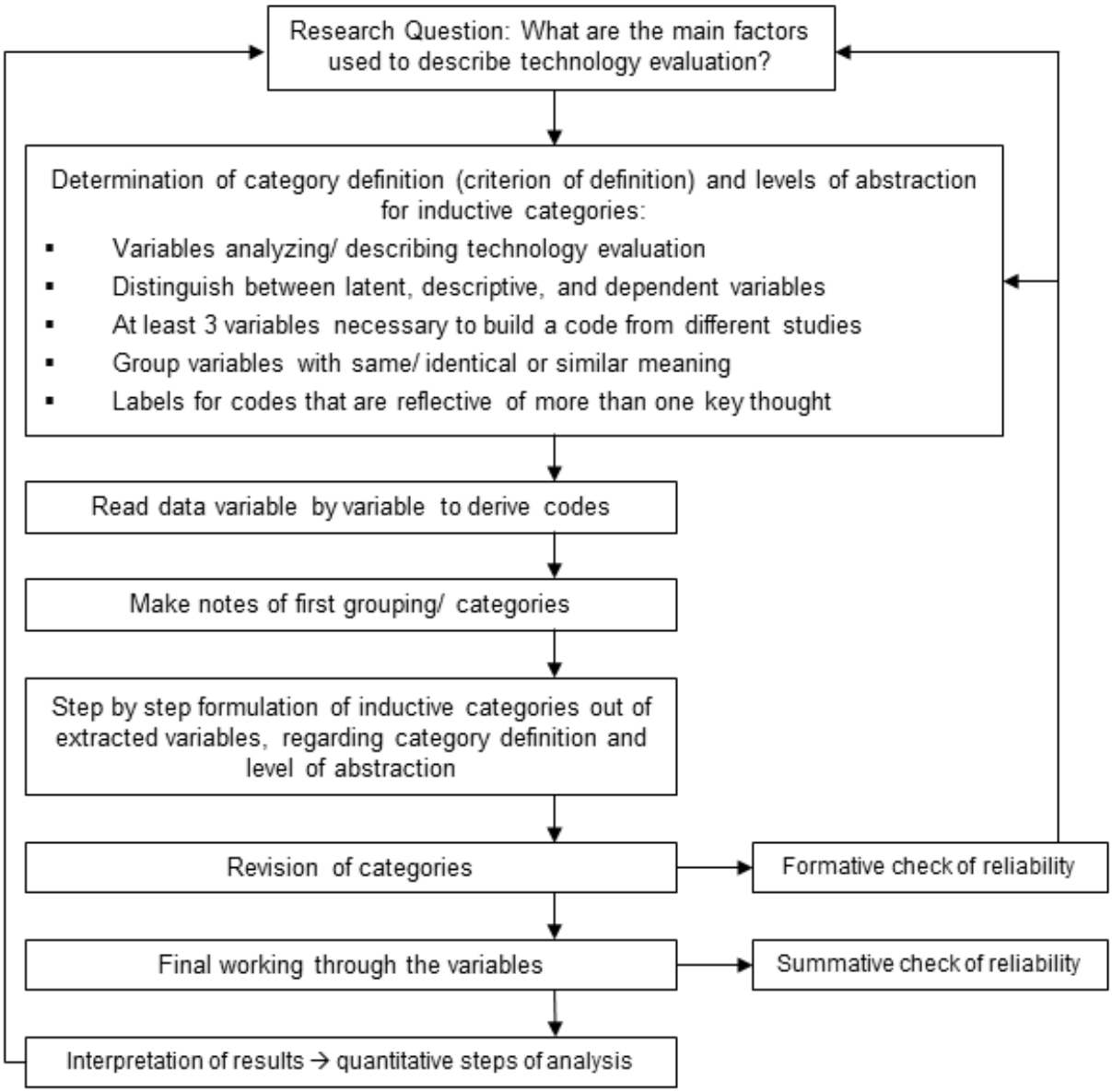

Figure 3.1: Procedure of inductive category development.

Remark: *formative check of reliability* ~ two researchers checked the agreement of categories while discussing cases of doubt and problems about the scope and overlapping of the categories; *summative check of reliability* ~ final working through the variables and codes, check of interrater reliability of the coding (how much researchers had overlaps to ensure reliability).

Source: adapted from Mayring (2000) and Schilling (2006).

In order to process the huge amount of information, the basis for coding a category was having at least three studies using the same variable. When a study reported findings from different contexts (i.e. supply chain actors, countries, or products), similar variables for both contexts were extracted (e.g. Mogendi et al., 2016a) counted double as focus was on consumer and farmer). Therefore, percentages in Table 3.1, Table 3.2 and Figure 3.2 are presented based on the total number of extracted variables, but not on total number of included studies.

Furthermore, variables referring to case-specific intrinsic (related to the physical aspects of a product, e.g. level of on-farm chemical use, organic-produced crops) or extrinsic (related to the non-physical part of the product, e.g. brand name, domestic versus imported food, patenting need) attributes (Bernués et al., 2003) were excluded from subsequent analysis as no common coding variable could be identified. This was also true for the study-specific factors political values, emotional involvement, and perceived standard of living. With respect to dependent variables, those derived from cluster analysis (i.e. segments) were too implicit to be grouped and coded across studies.

All coded variables were categorized as either dependent, latent, or descriptive variables. Dependent variables are a function of other variables and the explanation of its variation is of research interest. The independent (latent) variables normally explain the variation observed in dependent variables and are usually not explained by any other construct in the model (Hair et al., 2014). Additionally, descriptive (manifest) variables defined as consumer characteristics (e.g. gender, income, family status) or farmer/farming characteristics (e.g. age, farm size) are also considered as factors influencing dependent variables.

3.2.4 Data Analysis

Using coded groups of variables, descriptive statistics (i.e. frequency distributions) were applied to describe concepts used in the chain actor evaluation of food technologies. This was integrated into the multi-level ecological model of factors influencing behavior (Sallis et al., 2008). In the context of environmental influences on food choices, Story et al. (2008) presented an ecological model of individual factors (personal and psychological factors), social environments (networks, interactions with family, friends, peers, and others), physical environment (settings of where behavior takes place, such as home, schools, supermarkets), and macro-level environments (societal and cultural norms, food industry, agriculture policies), which was also related to the ecological framework by Bronfenbrenner (1979). This approach helps to understand how people behave while interacting with their environment (Sallis et al., 2008). In this review, this approach is used in the context of perception toward the individual, social, physical, and macro-level environments. For visualization and analysis of significant relationships between main factors, Gephi – a visualization and exploration software – by building networks, was utilized. Thereby, the ‘Circular layout’ is chosen – data are represented as a circle, with nodes (variable codes) arranged around the perimeter (dependent variable) and edges (relationships between variables) criss-crossing through the center of the network (Cherven, 2013).

To identify the most often reported significant relationships between variables a cut-off level of 4% was applied to avoid overload of less established constructs. The share of the specific relationship (e.g. 63 relationships of perceived benefits) in the total number of significant relationships (*N*=769) was calculated (63/769=0.08). In addition, factors from qualitative studies are used to justify outcomes from the quantitative research findings.

3.3 Results of the review

3.3.1 Description of included studies

This section essentially uses the same database as the systematic review in chapter 2, i.e. 183 studies dealing with new food technology evaluation by different chain actors. However, the data is extended by extracting factors measuring and influencing evaluation of new food technology. The study characteristics, targeted technologies and chain actors based on these 183 studies remain the same as presented in sections 2.3.1 and 2.3.2, however, are also shortly summarized in Table 3.1.

Table 3.1: Type of technology, data collection method, and variable type used by the included studies.

				Consumer	**Processor**	**Farmer**
No of studies (*N*=183), note: Mogendi et al. (2016a) counted double as focus was on consumer and farmer				169	2	13
Type of technology	Genetic modification (62%)			54%	1%	7%
	Non-GM biofortification (3%)			3%	0%	0%
	Fortification with food ingredients (23%)			23%	0%	0%
	Processing technologies (12%)			11%	1%	0%
Data collection	Primary	Quantitative	Survey	68%	1%	7%
			Experiment	12%	0%	1%
		Qualitative	Interviews	6%	0%	0%
	Secondary	Eurobarometer		5%	0%	0%
Type of variable (*N*=1,986)	Dependent			191	3	17
	Latent	Quantitative		873	8	38
		Qualitative		228	0	0
	Descriptive			550	3	89

Source: Own illustration.

With regard to variables used to describe chain actors' food technology evaluation, 1,986 variables were extracted (Table 3.1). The majority of these variables was obtained from

quantitative research, especially consumer studies, but also a few studies on farmers or processors. For qualitative studies, 228 latent variables were extracted and used for further analysis.

3.3.2 Frequency of factors in chain actors' evaluation behavior studies

By employing the procedure of inductive category development adapted from Mayring (2000), variables were grouped by consumer (quantitative approaches: 24 latent, 14 descriptive; qualitative approaches: 12 latent) and farmer studies (2 latent, 10 descriptive). Only 2 studies at processor level could be identified, hence no convergence of factors could be reached.

Following the ecological model by Story et al. (2008), more than 40% of the variables related to the physical (technology/product) or individual environment, while far fewer variables were categorized as macro-level (Figure 3.2). Strikingly, only 2% of the variables belonged to the social environment category.

Consumer: quantitative studies – Five categories of *dependent* variables were identified for consumer studies (Table 3.2). These are: likelihood/intention to adoption/acceptance, willingness to pay, attitude to food or technology, acceptance, and perceived risks and benefits.

When testing the various outcomes of variables and relationships according to the different dependent variables (Appendix C), as well as across included technologies (Appendix B), high similarities were obtained. Therefore, findings were aggregated for all proxy indicators of chain actors' evaluation.

In describing the dependent variables, *latent* factors of well-known theories such as Theory of Planned Behavior and Protection Motivation Theory as well as the Food (Technology) Neophobia Scale were applied. These included: subjective norm, perceived behavioral control, self-efficacy, response of product efficacy, vulnerability, response cost, and food neophobia. Those variable groups had a small share compared to other variable groups. It was observed that models used in studies are to a lesser extent based on well-established, rather tend of use other factors independent of theories. For the latter, the two most often applied latent variables were information assessment (knowledge, familiarity, and search for information) and level of trust in institutions. These were followed by attitude toward product or technology/innovation, as well as perceived benefit/convenience, risk (perceived risk and risk acceptance), and quality perception of product.

Individual *descriptive* factors, such as age, gender, education, income, and health care/ status, as well as presence of children/ household size, were most often used as influencing factors to dependent variables.

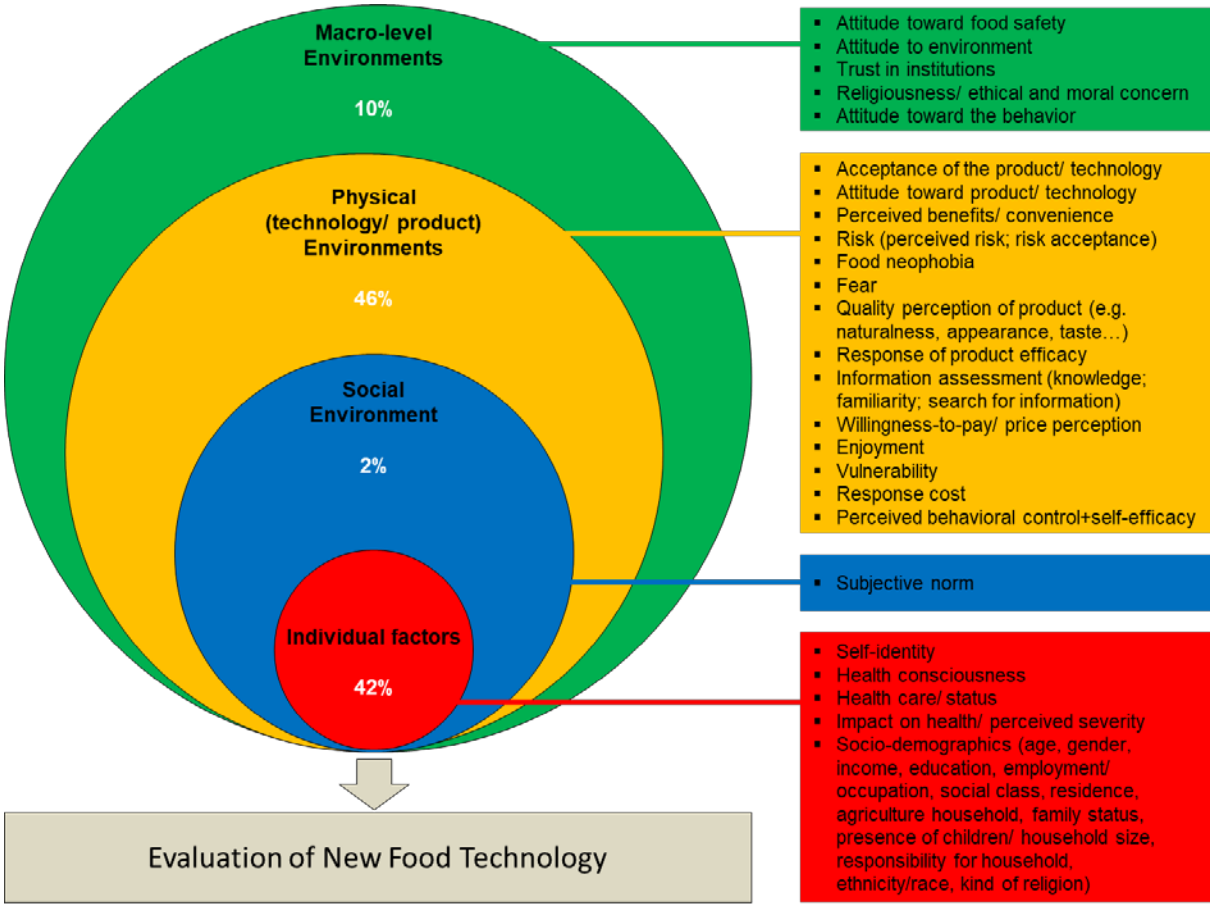

Figure 3.2: An ecological framework depicting the multiple influences on peoples' evaluation of new food technologies.

Source: Own illustration, adapted from Story et al. (2008).

Consumer: qualitative studies – The factor that was most often mentioned in qualitative studies in the context of evaluating new food technologies was related to the product itself (perceived characteristics of product), followed by individual factors, namely impact on health and perceived quality of life.

The comparison of results between the quantitative and qualitative studies showed that variables were similar but the order was different. Main differences included: characteristics of product and impact on health were more often mentioned in qualitative compared to quantitative studies. The factors risk and benefits were similar to that of quantitative studies. However, enjoyment was more and information assessment was less often stated in qualitative consumer studies. In addition, the variable trust in institutions was the second most

often used variable in quantitative consumer studies, but it turned out to be less interesting in qualitative consumer studies (second least used variable).

Table 3.2: Frequency table of variables of included studies (systematic review).

		Supply chain actor			
Type of variable	Method data collection	Consumer Variable name	%	Farmer Variable name	%
Dependent	Quantitative	Intention/Likelihood to accept	45%	Likelihood/probability of adoption	35%
		Attitude to food or technology	16%	Adoption	35%
		Willingness to Pay	16%	Perceived risks or benefits	29%
		Acceptance	15%		
		Perceived risks and benefits	9%		
Latent	Quantitative	Information Assessment (knowledge; familiarity; search of info)	18%	Perceived risks/benefits of product/seeds	66%
		Trust in Institutions	11%	Source of information	34%
		Attitude towards product or technology (innovation)	10%		
		Perceived benefit/convenience	9%		
		Risk (perceived risk; risk acceptance)	9%		
		Quality perception of product	7%		
		Impact on health/perceived severity	5%		
		Perceived behavioural control+self-efficacy	3%		
		Attitude to environment	3%		
		Religiousness/ethical and moral concern	3%		
		Willingness to pay/price perception	3%		
		Health consciousness	3%		
		Food neophobia	2%		
		Subjective norm	2%		
		Acceptance	2%		
		Vulnerability	2%		
		Attitude towards the behaviour	2%		
		Fear	2%		
		Self-efficacy	2%		
		Attitude towards food safety	2%		
		Response of product efficacy	1%		
		Enjoyment	1%		
		Self-identity	1%		
		Response cost	0%		
	Qualitative	Perceived characteristic of product	18%		
		Impact on health	11%		
		Perceived quality of life	11%		
		Quality of product	10%		
		Risk and health concern/vulnerability	9%		
		Enjoyment	9%		
		Knowledge/uncertainty of knowledge	8%		
		Benefits	7%		
		Responsibility to others and nature/subjective norm	6%		
		Impact on nature	5%		
		Trust in product and institutions	3%		
		Performance improvement	2%		
Descriptive	Quantitative	Age	17%	Farming practices	26%
		Gender	17%	Farm size	16%
		Education	16%	Education	11%
		Income	12%	Age	10%
		Presence of children/household Size	9%	Financial benefits	10%
		Health care/status	8%	Presence of children / household Size	7%
		Residence	5%	Farm location	6%
		Employment/occupation	4%	Income	6%
		Family status	3%	Barriers	4%
		Ethinicity/race	3%	Gender	4%
		Kind of religion/religious yes/no	2%		
		Agricultural household (farmer status)	2%		
		Responsibility of household	2%		
		Social class	1%		

Remark: Percentages are calculated for each sub-section, e.g. section 'consumer-latent-quantitative' is based on all latent variables at consumer level using quantitative approaches; *self-identity can be understood as a label that people use to describe themselves that suggests identification with a social group or category (Cook & Fairweather, 2007).

Source: Own illustration.

Farmer studies – *Dependent* variables of farmer studies can be summarized into three categories, i.e. likelihood/probability of adoption/acceptance, adoption, and perceived risks and benefits.

Farmer studies focused more on farmer and farming characteristics but not on *latent* variables. Only two latent variable groups could be identified, i.e. perceived risks or benefits of product/ seeds and source of information.

Included farmer studies also focused on *descriptive* farmer and farming characteristics. Thereby, farming practices (e.g. experiences, livestock, soil quality, and waiting period), farm size, education as well as financial benefits (e.g. saving of pesticides, yield advantages), and age were often included in models.

3.3.3 Significant relationships to measure chain actors' evaluation behavior

In the above section the percentages of variables was presented. The relationships between variables were analyzed using the following structure:

- Consumer evaluation studies:
  - Quantitative approaches, analyzing relationships between following variables:
    - latent → latent → dependent (Figure 3.3, and Appendix D)
    - descriptive → dependent (Figure 3.4)
  - Qualitative approaches, analyzing relationships between following variables:
    - latent → latent (Figure 3.5)
- Farmer evaluation studies, analyzing relationships between following variables:
    - latent, descriptive → dependent (Figure 3.6).

Consumer: quantitative studies – Within quantitative consumer studies, 8 *latent* factors met the 4% cut-off level, i.e. showed the most often significant relationships toward the dependent variable: (1) information assessment, (2) perceived benefits/ convenience and risk, (3) trust in institutions as well as (4) attitudes toward product or technology/innovation, (5) quality perception of the product, (6) impact on health, and (7) perceived behavioral control. The specific relationships are explained in more detail in the following paragraphs.

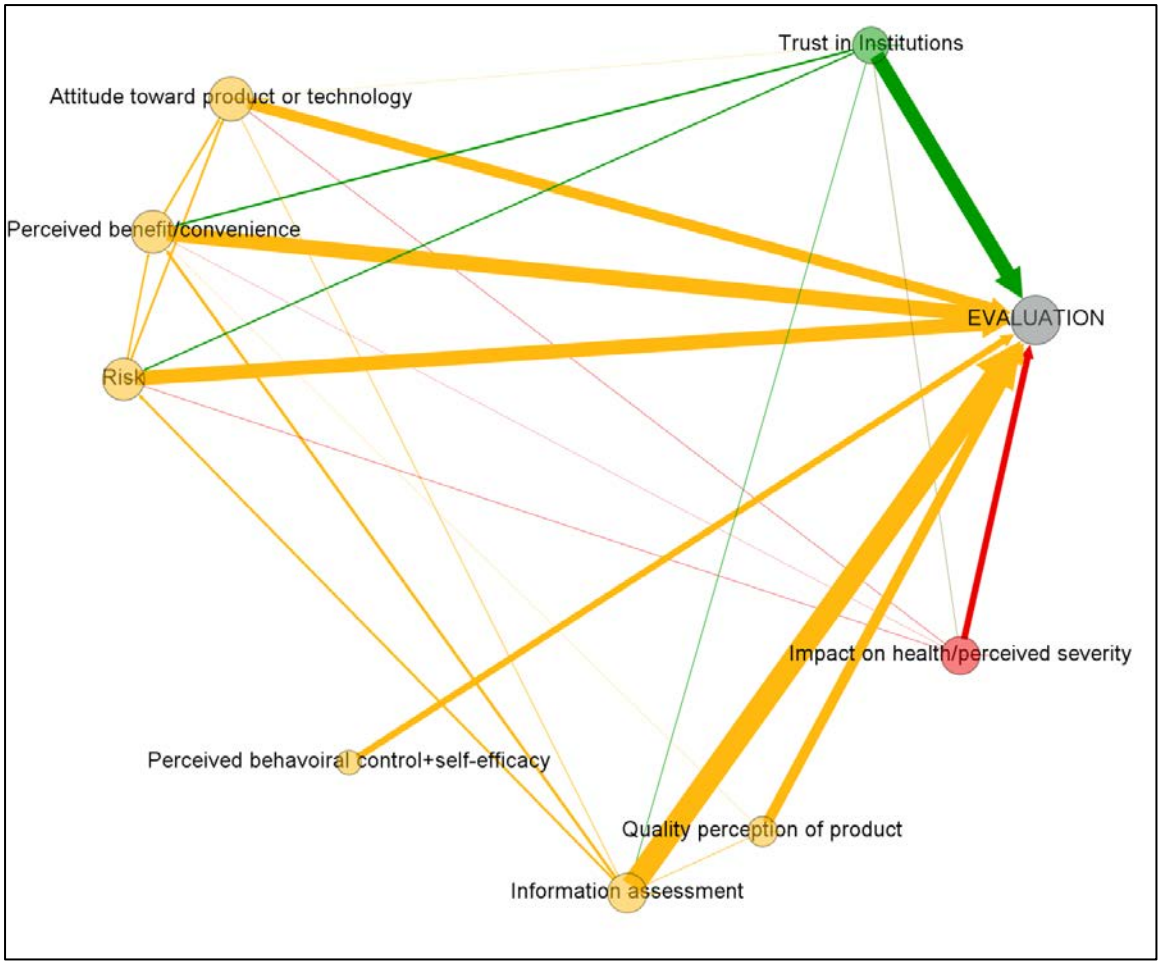

Figure 3.3: Significant relationships between latent and dependent variables (quantitative consumer studies) with a cut-off level of 4% (and its interrelationships).

Remark: red = individual factors; blue = social environments; yellow = physical environments; green = macro-level environments; edge thickness, or weight, represents association strength between nodes.

Source: Output of Gephi.

(1) *Information assessment* – There is a tendency for a positive relationship toward evaluation of new food technologies, i.e. the more knowledge a consumer has about, or the more familiar a consumer is with the new technology, the better and more positive is the food evaluation (with respect to GM: Amin et al., 2011; Baker & Burnham, 2001; Lusk et al., 2004; fortification: Annunziata et al., 2016; Brečić et al., 2014; and nanotechnology: Kim & Kim, 2015). For example, an experimental auction by La Barbera et al. (2016) demonstrated the positive effect of level of (subjective) knowledge about lycopene[6] on willingness to pay for functionalized healthy food in both auctions condition (hypothetical vs real). However, a survey with male consumers by Henson et al. (2008b) revealed a

[6] Measurement of knowledge: 'How much are you aware of the therapeutic properties of lycopene?' (scale 1=not much to 7=a lot) by La Barbera et al. (2016).

negative influence of (subjective) knowledge[7] on intention to buy lycopene-enriched functional food as a means to reduce the risk of prostate cancer. They assumed that consumers might be skeptical about the efficacy of this product to reduce the risk of prostate cancer (Henson et al., 2008b).

(2) *Perceived benefits and risks* – Both are important factors for the evaluation of new food technologies. Perceived benefits are defined both as useful, needed/necessary (Henson et al., 2008a), and healthy (Labrecque et al., 2006; Verbeke, 2005) as well as advantageous for the environment (Chen, 2008). Thereby, consumers who perceived a food technology innovation as beneficial exhibit positive evaluations (Prati et al., 2012; Steenis & Fischer, 2016). Perceived risk, which is associated with impact on health, being harmful/dangerous, negative impact on environment, and cause for concern/worry, unknown/uncertain (Henson et al., 2008a), had a negative influence on food evaluation among consumers (e.g. Coppola et al., 2014; Rodríguez-Entrena & Salazar-Ordóñez, 2013). Perceived benefits and risks mediate information assessment and trust in institutions, but both have an additional significant direct effect on evaluation of new food technologies.

(3) *Trust in institutions* – Overall, trust in institutions and stakeholders, e.g. government, food industry, farmers, scientists, and the media, increases the positive evaluation of new food technologies (with respect to GM: Gutteling et al., 2006; Kimenju & De Groote, 2008; Marques et al., 2015; fortification: Siegrist et al., 2008a; Vecchio et al., 2016; and processing technologies: Sapp & Downing-Matibag, 2009; Siegrist et al., 2008b). For example, respondents who hold a skeptical view of biotechnology companies were less likely to consume nutritionally enhanced GM cereals than those who trusted biotechnology companies (Onyango & Nayga, Jr., 2004).

(4) *Attitude toward product or technology* – Several studies found evidence that general attitude toward product or technology (innovation) is the most important explanatory attitudinal factor for novel food technology evaluations. This relationship was primarily positive (e.g. with respect to GM: Costa-Font & Gil, 2012; Laros & Steenkamp, 2004; Spence & Townsend, 2006; fortification: Carrillo et al., 2013; Cranfield et al., 2011; Krutulyte et al., 2011; and nanotechnology: Cook & Fairweather, 2007; Kim & Kim, 2015; Sodano et al., 2016). As illustrated in Figure 3.3, attitude toward product or technology (innovation) is significantly influenced by information assessment. Even though surveys showed that consumers have little knowledge about new food technologies (Siegrist,

[7] Measurement of knowledge: 'Do you have expertise related to medicine, nutrition, health care or are you employed in the food or nutrition industry?' (Yes/No) by Henson et al. (2008b).

2008), a majority of the people develop a view/an attitude toward this subject based on their pre-existing knowledge and values as suggested by Lyndhurst (2009).

(5) *Quality perception of the product* – In the actual purchase decision, various factors are shown to be taken into account, e.g. appearance, taste, naturalness, and healthiness, all categorized as quality perception of the product. The intrinsic attribute product appearance[8] was the most important factor influencing the decision to purchase irradiated papaya for Brazilian consumers (Deliza et al., 2010). For Italian consumers, appearance[9] negatively affected the willingness to pay a premium price for functional snacks before tasting (non-significant after tasting) as consumer do not believe that these products are appealing (Pappalardo & Lusk, 2016). Naturalness[10] appeared to be an important and positive technology feature for consumers with regards to GM foods (Hudson et al., 2015; Ronteltap et al., 2016). Technologies that were seen as more natural and newer were perceived less risky and more beneficial (Hudson et al., 2015). In terms of direct effects on dispositions to biotechnology, motivation to find natural foods[11] had a very strong negative effect (Lockie et al., 2005). Respondents for whom naturalness of food was important perceived more risks to be associated with nanotechnology compared to respondents who considered naturalness of foods to be less important (Siegrist et al., 2008b). Concerning perceived healthiness, this attribute had a positive influence on purchase intention for functional food (Dobrenova et al., 2015), GM food (Hu et al., 2009) and food nanotechnology (Sodano et al., 2016). Figure 3.3 shows that quality perception of the product mediates information assessment.

(6) *Impact on health* – Regarding impact on health, studies can be distinguished based on how a variable was conceptualized. Some studies measured perceived health impact of the product or the applied technology. Others measured perceived severity of a health threat. Depending on the conceptualization used, the influence on the evaluation of new food technologies was positive or negative. Measuring perceived negative health concern toward GM food had a negative effect on consumers' willingness to purchase GM food

[8] Measurement of appearance: In an experimental design by Deliza et al. (2010) the appearance of the fruit in terms of degree of blemishing varied [from free of blemishes (good appearance) to few blemishes (regular appearance)], but size and the color were kept constant throughout the experiment.

[9] Measurement of appearance: 'Extent to which food looks appealing.' using a best-worst scale approach by Pappalardo & Lusk (2016) .

[10] Measurement of naturalness: 'Apple Cisgenesis: Attitudes to artificially introducing a gene that exists naturally in wild/crab apples which provides resistance to mildew and scab' (scale 1=totally agree that it is fundamentally unnatural to 4=totally disagree) by Hudson et al. (2015); 'This (GM) bread is unnatural' (scale 1=totally disagree to 5=totally agree) by Ronteltap et al. (2016).

[11] Measurement of natural content: Ratings of several statements (contains no additives; contains natural ingredients; contains no artificial ingredients; certified free of chemical and hormone residues; is as unprocessed as possible; is prepared in a way that preserves its natural goodness; scale 1=strongly agree to 5=strongly disagree) by Lockie et al. (2005).

(Amin et al., 2011), as was perceived severity of eating irradiated meat (Crowley et al., 2013). Nevertheless, for the case of severity of a health threat (e.g. frightened of the possibility getting cancer or memory loss), the intention to choose fortified or functional food increased (Cox et al., 2004; Cox & Bastiaans, 2007; Henson et al., 2010).

(7) *Perceived behavioral control* – This factor is part of the Theory of Planned Behavior (Ajzen, 1991) and comprises components that reflect beliefs about controllability and about self-efficacy (Ajzen, 2002). The latter also belongs to the Protection Motivation Theory by Rogers (1975) and refers to the individual's belief that they can cope with the health threat by a recommended behavior, e.g. buying a new food product. In line with previous investigations on the construct perceived behavioral control (Ajzen, 2002; Povey et al., 2000), self-efficacy was more often significantly influencing consumers' new food technology evaluation than controllability. A positive influence of self-efficacy on consumers' evaluation of new food technologies was demonstrated with respect to GM (Cox et al., 2008), biofortification (De Steur et al., 2015; Mogendi et al., 2016a), and fortification (Cox et al., 2004; Henson et al., 2008b; Henson et al., 2010; Tudoran et al., 2012). This was also highlighted in the context of Australian consumers' intentions to consume conventional and novel sources of long-chain mega-3 fatty acids (e.g. GM food), where self-efficacy (confidence to consume) was the most important predictor (Cox et al., 2008).

Many quantitative research studies at consumer levels test hypotheses about the effect of sociodemographic characteristics (individual factors) on food technology evaluation (Figure 3.4). Findings indicate inconsistency. *Descriptive* factors that were most often reported as significant are: (1) age, (2) gender, (3) educational and income level, (4) health care/status, (5) household size and presence of children, (6) residence and (7) religion and ethnicity, and those are analyzed below in more detail.

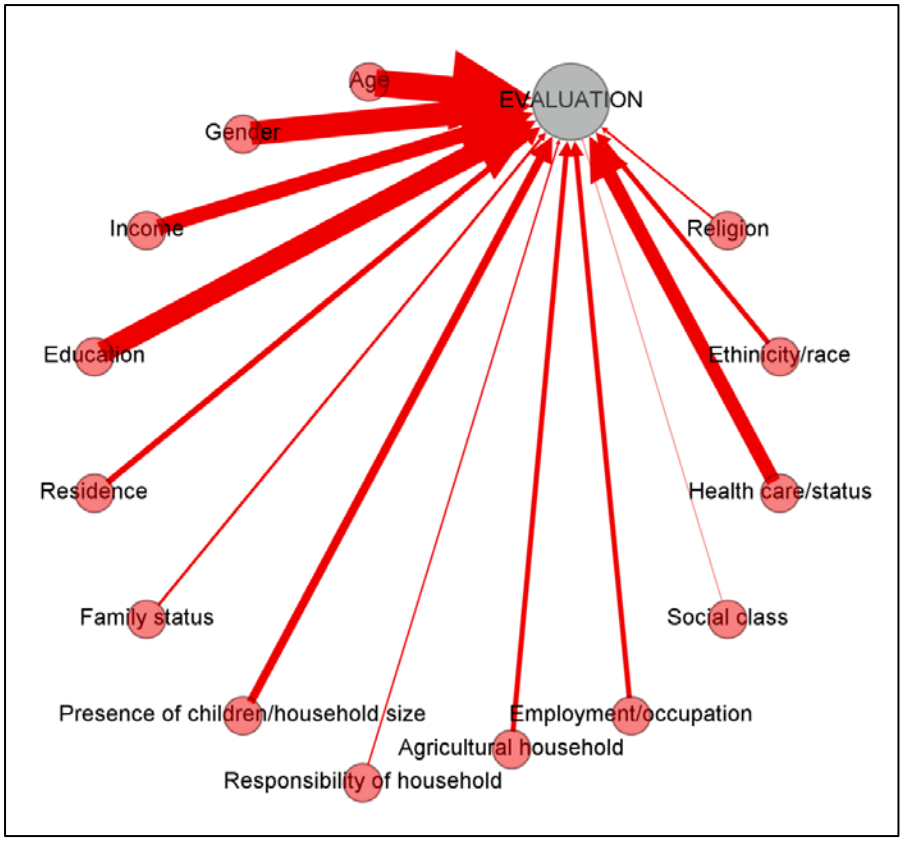

Figure 3.4: Significant relationships between descriptive and dependent variables (quantitative consumer studies).

Remark: red = individual factors; edge thickness, or weight, represents association strength between nodes.

Source: Output of Gephi.

(1) *Age* – For age, positive and negative relationships were observed. On the one hand, studies demonstrated that older people were less willing to use or buy functional food (Brečić et al., 2014; Cranfield et al., 2011; Verneau et al., 2014) or GM food (Canavari & Nayga, 2009; Hudson et al., 2015), were less accepting nanotechnology for food production (Kim & Kim, 2015), or were less willing to pay for GM food (Lusk et al., 2004). But, on the other hand, there are studies that show older people who were willing to pay more for innovative food (with respect to GM: Lusk & Rozan, 2008; non-GM biofortification: Oparinde et al., 2016; fortification: Kavoosi-Kalashami et al., 2017; Siegrist et al., 2008a; Vecchio et al., 2016), had less fear toward GM foods (González et al., 2009; Laros & Steenkamp, 2004; Sjöberg, 2008; Titchener & Sapp, 2002), or had higher intention to buy functional food or nutraceutical products (Henson et al., 2008b).

(2) *Gender* – Results of gender influences on food evaluation seem to be more consistent. Overall, compared to men, women evaluated GM foods (Chen, 2011b; Govindasamy et al., 2008; Lusk & Rozan, 2008; Napier et al., 2004; Zepeda et al., 2003) as well as food produced by nanotechnology more negatively (Sodano et al., 2016; Spence & Townsend,

2007) but were more attentive to healthy life including healthy food and more willing to try functional food (Annunziata et al., 2016; Chen, 2011a; Coppola et al., 2014). There are also a few studies that have demonstrated that men were more reluctant toward new food than women (Cranfield et al., 2011; Nayga, Jr. et al., 2006; Sjöberg, 2008).

(3) *Education and income* – In terms of education and income level, different studies find varied effects on food evaluation. Thereby, a higher education and/or higher income resulted in higher positive evaluation of novel food technologies (with respect to GM: Abdulkadri et al., 2007; Laros & Steenkamp, 2004; Pardo et al., 2002; fortification: Brečić et al., 2014; Kavoosi-Kalashami et al., 2017; Landstrom et al., 2007; and nanotechnology: Matin et al., 2012; Sodano et al., 2016). Other studies showed that consumers with higher education and/or income had a negative perception toward new food technologies (Chen et al., 2016; Giamalva et al., 1997; Poortinga, 2005; Zhang et al., 2016; Zheng et al., 2017).

(4) *Health care/status* – Both terms are often used with GM and functional food studies and results tend to show positive influences. A positively perceived health status increased the likelihood to use a functional food ingredient were observed (Cranfield et al., 2011). It is also reported that physical exercise and a higher body mass index positively affected evaluation of GM and functional food, respectively (Brečić et al., 2014; Cox et al., 2008). It seems consumers who are health-conscious more often used functional foods or contrarily those consumers who are willing to compensate for an unhealthy lifestyle (De Jong et al., 2003). Furthermore, the health status of significant others (e.g. sickness, overweight of a family member) had a positive impact on functional food evaluation (Kavoosi-Kalashami et al., 2017; Verbeke, 2005), but a negative influence on GM food evaluation (Cox et al., 2008; Zepeda et al., 2003).

(5) *Household size* – The larger the number of household members, the higher the consumption of functional food (Brečić et al., 2014) as well as their willingness to pay for it (Kavoosi-Kalashami et al., 2017). However, when there were young children in a household, willingness to consume or pay more for GM food was lower (Chen et al., 2016; Thorne et al., 2017). This is similar for functional food in a study by Annunziata et al. (2016), but different for Vecchio et al. (2016) who showed a higher willingness to pay for functional food.

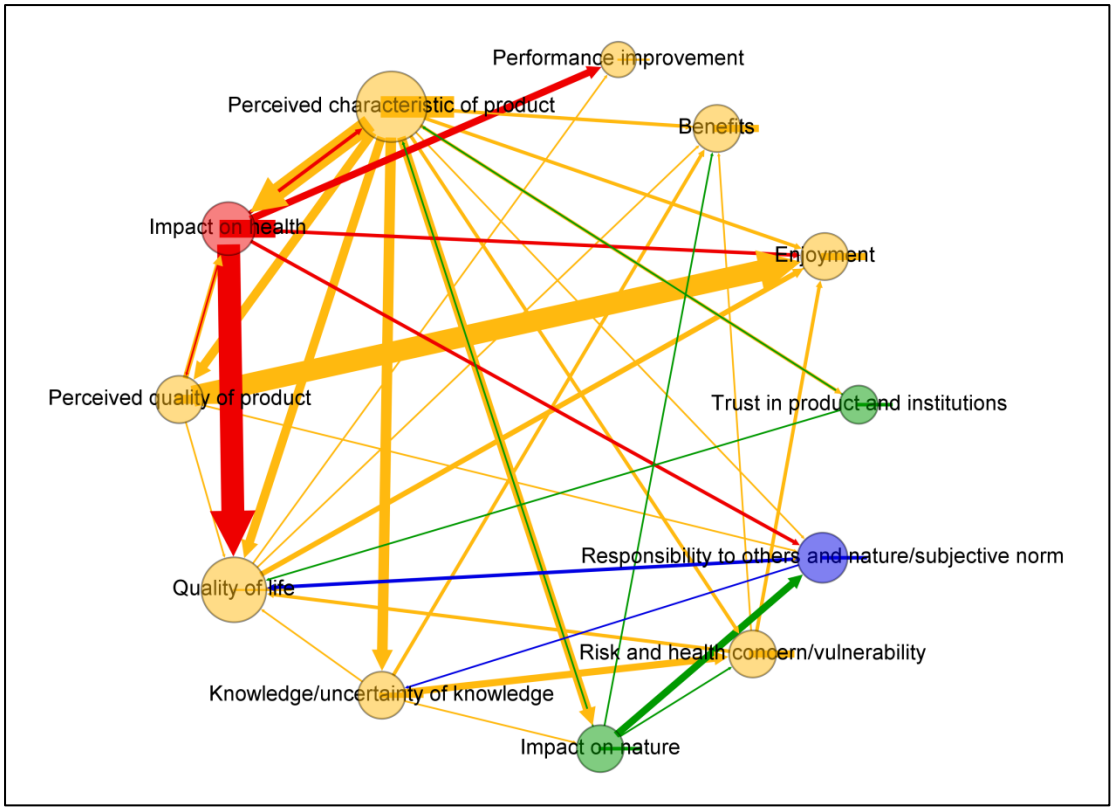

Figure 3.5: Relationships between variables of qualitative consumer studies.

Remark: red = individual factors; blue = social environments; yellow = physical environments; green = macro-level environments; edge thickness, or weight, represents association strength between nodes.

Source: Output of Gephi.

(6) *Residence* – Living in urban or rural areas also affects consumers' food technology evaluation that are rather mixed (Canavari & Nayga, 2009; Olofsson et al., 2006; Onyango & Nayga, Jr., 2004). There were also a few studies that reported a higher willingness to try or pay by urban people for functional food (Coppola et al., 2014) or GM food (Ali et al., 2016), while others reported a negative influence for GM food (Govindasamy et al., 2008). Belonging to an agricultural household negatively influenced functional food consumption (Brečić et al., 2014) as well as the willingness to pay for GM food (Thorne et al., 2017).

(7) *Religion and ethnicity* – Both influence consumers' food technology evaluation, with a tendency to negative relationships. Religious consumers showed a negative effect in support for biotechnology (Costa-Font & Mossialos, 2005). For ethnicity, Blacks had more moral opposition to GM of plants than Whites (Knight, 2007a; Knight, 2007b), but Hispanics demonstrated more support than Whites (Knight, 2007b).[12]

[12] Results are based on a causal model examining the intervening effects of knowledge, morality, trust, and benefits.

Consumer: qualitative studies – Given that means-end-chain analysis uses a laddering technique, a dependent variable could not be identified, though the focus is on the relationships between factors. Therefore, data from qualitative studies were interpreted through comparison of most often mentioned relationships between latent variables, as derived from the quantitative studies. First of all, Figure 3.5 shows that knowledge is related to perceived risks and benefits (Barrena et al., 2017; Grunert et al., 2001; Krutulyte et al., 2008), and also that perceived risks are related to perceived benefits (Krutulyte et al., 2008) as has been observed in a number of quantitative consumer studies. In addition, qualitative studies demonstrated the mutual relationship between perceived characteristics of product and trust in product/institutions, on the one hand, or perceived benefits on the other (Hagemann & Scholderer, 2009). Furthermore, the perception of the quality and characteristics of the product were related to impact on health (Bredahl, 1999; Sonne et al., 2012). These are potential factors that may have an (mediated) effect on the evaluation of new food technologies by consumers.

Farmer studies – Model-based studies at farmer level focused on descriptive factors. Only two *latent* factors could be categorized based on extracted data (Figure 3.6), i.e. (1) perceived risks or benefits of product and (2) source of information.

(1) *Perceived risks and benefits* – Regarding perceived risks and benefits of the product, a high level of ambiguity aversion (Barham et al., 2014) or the perceived advantages of disease-resistant and flavor-enhancing crops (Luh et al., 2014) positively influence GM food evaluation.

(2) *Source of information* – Empirical results by a GM seed evaluation study in Taiwan by Luh et al. (2014) indicated that information acquired through social networking increased the probability of adoption. If government reports with scientifically underpinned information about GM seed were provided to farmers, the risk perception toward the use of GM seeds among U.S. farmers' decreased, hence adoption was more likely (Guehlstorf, 2008). US farmers were also more likely to be influenced by their first-hand or local experiences than by state or expert observations (Kaup, 2008).

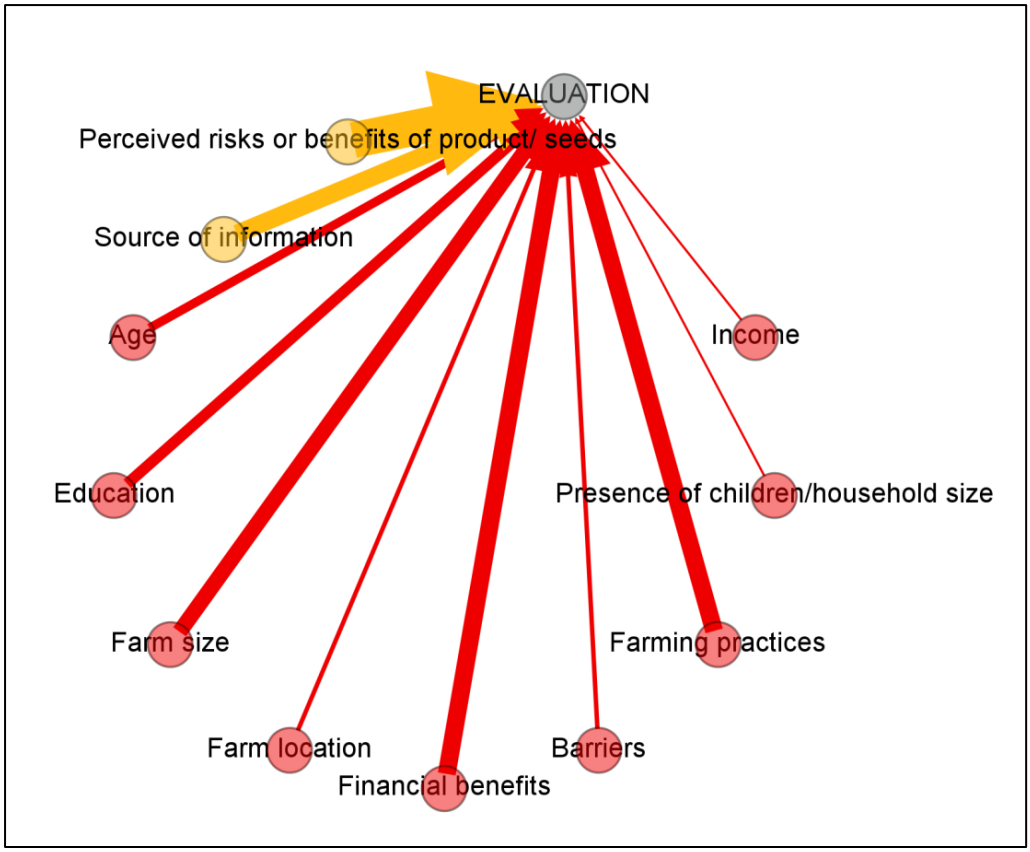

Figure 3.6: Significant relationships between latent, descriptive and dependent variables (farmer studies).

Remark: Red = individual factors; yellow = physical environments; edge thickness, or weight, represents association strength between nodes; gender had no significant relationship.

Source: Output of Gephi.

Three groups of significant *descriptive* factors can be identified: (1) financial benefits and barriers, (2) farming practices and farm size, and (3) education and age on new food technology evaluation.

(1) *Financial benefits and barriers* – Both can be linked with perceived risks and benefits as latent variables. For example, having yield advantages, and insecticide or herbicide savings, positively influenced evaluation of GM crops (Useche et al., 2009). Farmers facing credit-constraints, however, had a lower willingness to pay for GM crops (Basu & Qaim, 2007). Regarding time commitment, full-time farmers were less likely to adopt a new technology when there is a greater income-related uncertainty vis-á-vis the earnings from farming activities (Luh et al., 2014).

(2) *Farm size* – Farm size is another key factor. The bigger the land area owned, the higher the probability of GM crop adoption (Basu & Qaim, 2007; Useche et al., 2009). For farming practices and experiences mixed results are reported. While the evaluation of GM banana

was positively affected by the extent of farming experiences[13] in East African highlands (Edmeades & Smale, 2006), the opposite was found for banana farmers in Taiwan (Luh et al., 2014)[14] .

(3) *Education and age* – Various demographic factors were found to be significant, e.g. older farmers were less likely to adopt GM crops (Breustedt et al., 2008; Oparinde et al., 2017; Zhang et al., 2017) than less educated ones (Edmeades & Smale, 2006; Tudoran et al., 2012).

3.4 Discussion

3.4.1 Main outcomes and future research

The systematic review in this chapter provides a comprehensive overview of studies determining key factors that influence new food technology evaluation among supply chain actors. The findings in this chapter indicate that most studies dealt with GM foods, instead of other food innovation like processing technologies (e.g. PEF) or non-GM biofortification (e.g. conventional and agronomic approaches). It is possibly a consequence of associated public controversy (Frewer et al., 2011; Gupta et al., 2012). There is also an imbalance in terms of study location and supply chain actor, with most studies targeting consumers in developed countries.

In this chapter, 1,986 variables from 94% quantitative and 6% qualitative studies were analyzed. For quantitative consumer studies, the variables were grouped to 24 latent factors by applying inductive category development. Out of these 24 factors, 8 factors account for about 72% of all factors mentioned across the samples and 55% of significant relationships, i.e. trust in institutions, information assessment, perceived risks, perceived benefits, attitudes toward product or technology, quality perception of the product, perceived behavioral control (including self-efficacy), and impact on health. Their impact on explanation of consumers' food evaluation shows positive and negative relationships depending on the technology, study setting, and type of measurement. Especially the importance of trust, knowledge, and perceived risks and benefits in the context of consumer evaluation behavior by various technologies (Gupta et al., 2012), but also particularly in the food context (Frewer et al., 2013; Lusk et al., 2014; Rollin et al., 2011; Ronteltap et al., 2007), is supported by earlier reviews. Following the results of various reviews, including this systematic overview, the factors that

[13] Measurement of farming experience: Ratio of years of experience to age of person in charge of banana production by Edmeades & Smale (2006).
[14] Measurement of farming experience: Experience with planting bananas (in months) by Luh et al. (2014).

were found to influence consumer evaluation of one technology contribute in shaping the evaluation of other technologies (Gupta et al., 2012). Nevertheless, some factors (for example ethical and moral concern, subjective norm and enjoyment) have been less frequently studied throughout different chain actors' technology evaluations as shown in the ecological framework (Figure 3.2).

While quantitative studies are often depending on well-established theories and models, which lead to a "path-dependent development", qualitative studies may open avenues for future (quantitative) research through in-depth exploration and identification of emerging relationships. Accordingly, this review also embraces qualitative research studies in addition to quantitative studies. Thereby, qualitative research supports the identified factors by quantitative studies, with the exception of trust. Trust is less often stated in qualitative research than in quantitative research. This might be caused by the difference of trust to other variables which are related to the influence of individual factors, social environment, as well as the perception toward the product/technology, whereas trust is on a higher abstracted level and might be processed subconsciously. But trust in institutions and also in information reduces complexity, as not all pros and cons of a new food technology can be assessed in everyday life decision situations (Lusk et al., 2014), especially when consumers have little knowledge about a technology (Siegrist & Cvetkovich, 2000).

The results of this systematic review open avenues for future research. First, in terms of the scope of studies, there is a need for research in developing regions, at farmer or processor levels, and non-GM innovations (e.g. processing technologies). As shown in this review, GM evaluation research is dominating in developed countries, but most GM crops are cultivated nowadays in developing regions (ISAAA, 2017), demonstrating the gap of chain actor evaluation research. Although the importance of GM still increases (ISAAA, 2017), other food technologies, such as the utilization of food waste, e.g. to gain high-added value ingredients (Galanakis, 2012); alternative sources of proteins, such as seaweeds and insects (Tian et al., 2016); but also synthetic biology, CRISPR/Cas (Katz et al., 2018), and 3D printers (Dankar et al., 2018) are also advancing.

Second, while a standardized approach to define and measure food consumer evaluation and its proxy indicators (like information assessment or attitude toward product or technology) in a consistent way will improve consumer food research and its comparability (Hess et al., 2016; Mogendi et al., 2016b), it requires insights into the effect of operationalization of variables, and the methods that are used to collect information on those variables. Nevertheless, based on a large database of consumer studies, one could develop a Food Technology Acceptance

Model that consists of the most frequently reported variables/constructs and significant relationships, and validate and apply it to specific contexts. Such a unifying theory of food technology evaluation seems to be lacking and has also been stated by other scientists (Bredahl et al., 1998; Hess et al., 2016; Lusk et al., 2014; Mogendi et al., 2016b). While there are researchers criticizing such theory building for controversial food technologies (Lusk et al., 2014), the important predictors in this study have been confirmed across various food technologies (Frewer et al., 2013; Gupta et al., 2012; Ronteltap et al., 2007) and lend support for an overall explanatory model that does not rule out context-specific variables, similar to those found in the Theory of Planned Behavior.

Third, food innovation adoption literature on farmers and processors is quite limited. There is a need to investigate in more detail factors influencing farmers' and processors' evaluation behavior toward new food technologies. This is important as the understanding of the evaluation behavior of all food supply chain actors is important in order to develop a successful innovation diffusion (Bigliardi & Galati, 2013; Bröring, 2008; Grunert et al., 2005). Thereby, factors from other research contexts can give important additional adoption factors that can be adapted to the food context. For farmers it is literature on the adoption of precision agriculture (e.g. Adrian et al., 2005) or information technology (e.g. Aleke et al., 2011) and for processors future research can adapt factors from the research area of information technology (e.g. Kinsey & Ashman, 2000), organic food products (e.g. Shanahan et al., 2008), or environmental management systems (e.g. Massoud et al., 2010). These factors will help to develop a supply chain evaluation research approach in the future.

3.4.2 Reflection on strengths and limitations

According to the broad scope of this systematic review, both strengths and limitations must be considered. On the one hand, it synthesizes the results of food technology evaluation studies throughout different technologies and supply chain actors and, thereby, improves the understanding of the key factors driving chain actors' evaluation behavior. Due to the comprehensive scope, this chapter mainly focuses on findings across technologies, rather than between. Nevertheless, the table in Appendix B provides significant relationships between latent variables and food evaluation for each technology category in quantitative consumer studies. On the other hand, the heterogeneity of this systematic review does not allow to conduct a reliable meta-analysis. Furthermore, when interpreting the results, one needs to take into account the occurrence of publication bias as well as the discussion about overestimating p-values and missing presentation of effect sizes (Hirschauer et al., 2016) as well as missing information on construct measurements. Due to the publication bias, which

assumes that research reports often present only significant relationships (Petticrew & Roberts, 2006), a calculation of the share of significant to non-significant evaluation relationships was not advisable. To enhance the transparency of research, researchers should further invest in providing information on the concepts they measure. Even though this systematic review is considered to be the first to analyze significant effects of targeted factors of food technology, the results are interpreted using the statistical thresholds of significance.

3.5 Implications and conclusions

By providing a comprehensive understanding of the critical factors for new food technology evaluation, this review provides factors to build a framework for future studies related to chain actors' food evaluation, specifically by helping to clarify how the factors of different groups can vary. Thereby, this review has identified research gaps in the current research landscape, e.g. limited research on farmer and processor evaluation behavior, on non-GM technologies, in developing countries, and the inconsistency of variable measurements. These research gaps merit consideration in future research in order to better understand the adoption of new food technologies along the supply chain and, in turn, to develop successful implementation strategies. From a policy-related perspective, insights of the consolidated factors influencing consumers' evaluation behavior can serve as the basis for the development of public-outreach strategies, for instance, through identifying crucial building blocks for communicating research results. Connecting to this, the next chapter develops and applies a Food Technology Acceptance Model at consumer level and empirically tests it on the example of 3D-printed food.

Part III: Empirical consumer studies

4 Consumers' evaluation of 3D-printed food: A comparison of the Food Technology Acceptance Model and the Theory of Planned Behavior

Chapter 4 answers Research Question 3 and its respective sub-questions:

RQ 3: What determines consumers' evaluation toward new food technologies exemplified on 3D food printer?

RQ 3.1: What drives consumers' evaluation of 3D-printed food?

RQ 3.2: How will consumers' evaluations of 3D-printed food differ to other new food technologies?

RQ 3.3: How will the model prediction of a proposed Food Technology Acceptance Model differ to a well-known theory represented by the Theory of Planned Behavior?

This chapter is based on the following publication:

Kamrath, C.; Bröring, S.; De Steur, H. (2019): Explaining intention to consume 3D printed food – An application of the Food Technology Acceptance Model and the Theory of Planned Behavior. *Submitted to: Journal of Product Innovation Management.*

4.1 Introduction

4.1.1 Food technology evaluation research

Consumer evaluation of new food technologies has been widely studied in various settings, and various measures, such as acceptance, adoption, perceptions, attitude, intention and willingness-to-pay as also presented in Table 1.1 (Hess et al., 2016; Mogendi et al., 2016b). These measures are part of several theories that are used to analyze the determinants of individuals' behavior and action. The diversity is shown by a comprehensive overview of 60 social-psychological models and theories of behavior presented by Darnton (2008). However, these theories are hardly used in the context of food technology evaluation research on consumers (see section 2.3.3), such as the Theory of Planned Behavior (TPB) (Ajzen, 1991) applied in the context of genetically modified food (Ghoochani et al., 2017; Prati et al., 2012), functional food (Chen, 2017; Patch et al., 2005), and nanotechnology (Cook & Fairweather, 2007). Although the TPB is one of the best developed approaches within social psychology (Wolske et al., 2017), these studies added different factors to the originally model (Table 2.1), demonstrating that a comprehensive model for new food technology evaluation is lacking (Bearth & Siegrist, 2016; Bredahl et al., 1998; Frewer et al., 2016; Lusk et al., 2014). A common model for food technology evaluation would benefit the understanding what drives food technology evaluation across different consumer groups. By drawing upon the results of an extensive systematic review by Kamrath et al. (2019)[15] (see chapter 3) about factors influencing chain actors' evaluation of several new food technologies (e.g. genetic modified food, functional food, processing technologies), this chapter proposes a Food Technology Acceptance Model (FTAM) specifically at consumer level. On the case of 3D-printed food, the FTAM is compared to the well-known TPB, and thus, the theoretical aim of this chapter is to examine the contribution of FTAM to the TPB.

4.1.2 Consumers' acceptance of new food technologies, especially 3D-printed food

In the past centuries, several food processing technologies have been implemented in the food supply chain to provide safe, nutritious and acceptable food products (Augustin et al., 2016; De Steur et al., 2017a; Floros et al., 2010; Misra et al., 2017). Among others, especially cold plasma, pulsed electric fields, high hydrostatic pressure, ohmic heating, radiofrequency electric fields, nanotechnology and UV irradiation have raised much attention (Augustin et al., 2016; Misra et al., 2017; Tian et al., 2016). A recent development is 3D printing, also known as

[15] The review Kamrath et al. (2019) is largely presented in chapter 3.

additive manufacturing, which is expected to provide a wide spectrum of new possibilities within the food industry, and may yield in many innovations in the food manufacturing, retail and catering sectors (Brunner et al., 2018). 3D food printing is a digitally controlled, robotic construction process that creates food pieces in a layer-by-layer manner (Sun et al., 2015b) by using cartridges filled with soft edible matter (e.g. food pastes, purees, powders, doughs, batters, liquids, and gels) made from various raw materials (e.g. sugar, chocolate, cheese, flour, meat, fruit or vegetables) (Lupton & Turner, 2018). At present, 3D food printers are used to make pizza, pasta, cookies, chocolates and many other food (Lipton, 2017; Sun et al., 2018). It has the potential to develop healthy foods, using alternative protein sources or customizing products based on individuals' nutritional needs, while it could also help to reduce waste for food manufacturers through on-demand printing (Derossi et al., 2019; Tian et al., 2016). As such, 3D food printing is considered to be a promising technology with many possible applications in the field of sustainable development and, therefore, has the potential to revolutionize the food system (Portanguen et al., 2019; Sun et al., 2018; Yang et al., 2017). However, to succeed in the marketplace, new technologies such as 3D food printer require consumer acceptance (Augustin et al., 2016; Floros et al., 2010), which makes it a relevant and topical case for a consumer study.

Due to the novelty of applying 3D-printing on processing food, only little research has focused on how people perceive this food technology. Two studies from Australia (Lupton & Turner, 2018) and Switzerland (Brunner et al., 2018) showed that initially knowledge of consumers was low, while they had an a priori negative attitude, mostly related to the fear of eating unnatural and artificial food. Whereas provision of information on 3D-food applications and their potential benefits did not affect the Australian consumers' skepticism, it seemed to have an effect on the evaluation of the nutrition-conscious and convenience-oriented consumers in Switzerland. Findings of studies on Italian and UK consumers demonstrated that perceived risks of 3D-printed food is centered on health and environmental concerns (Bravi et al., 2017; Gayler et al., 2018). The outcomes of these studies presented different factors influencing consumers' evaluation of 3D-printed food, such as several perceived benefits and risks, naturalness and knowledge. Due to the limited number of studies focusing on consumers' evaluation of 3D-printed food, this chapter contributes to a better understanding of consumers' acceptance. To this end, it investigates German consumers' decision making toward 3D-printed food but also to consumers' general new food technology evaluation. Hence, the empirical aim of this chapter is to identify the factors influencing consumers' evaluation of 3D-printed food and compare it to the extended literature.

As derived from the previous sections, this chapter investigates three research questions:

- What drives consumers' evaluation of 3D-printed food?
- How will consumers' evaluations of 3D-printed food differ to other new food technologies?
- How will the model prediction of a proposed Food Technology Acceptance Model differ to a well-known theory represented by the Theory of Planned Behavior?

Hence, this chapter contributes (i) from an empirical perspective by adding to the current understanding of consumers' evaluation of 3D-printed foods in Germany compared to other new food technologies, and (ii) from a theoretical perspective as far as the development of an integrative theory that is relevant for future food technology evaluation research.

4.2 Literature review, research models and hypotheses

4.2.1 The new proposed Food Technology Acceptance Model

The hypotheses for a proposed Food Technology Acceptance Model are developed based on results of the systematic review of Kamrath et al. (2019) by reflecting the main 8 identified factors: (1) information assessment, (2) perceived benefits, (3) perceived risks, (4) trust in institutions, (5) attitudes toward product or technology/innovation, (6) quality perception of the product, (7) impact on health, and (8) perceived behavioral control.

Knowledge about a new technology has a positive influence on consumers' food evaluation. For example, consumers who understood basic scientific concepts associated with basic biology and genetic modification had a significant higher perception of benefits of biotechnology in Europe (Pardo et al., 2002). For functional food, a significant, positive relationship between knowledge and consumption was found (Brečić et al., 2014; Labrecque et al., 2006). In the case of 3D-printed food, the study by Brunner et al. (2018) showed that gained knowledge by consumers through provided information during the study impacted consumers' attitudes and improved their overall opinion of 3D-printed food. Consequentially, it is assumed that the more knowledge a consumer has, the higher is his/her perception of potential benefits of 3D-printed food and decreases his/her perception of risks.

H_{1a}: Subjective knowledge has a positive effect on perceived benefits.

H_{1b}: Subjective knowledge has a negative effect on perceived risks.

H_{1c}: Subjective knowledge is positively related to intention to consume 3D-printed food.

Some food attributes like their benefits are credence attributes (Darby & Karni, 1973), which cannot be directly observed by consumers before or after consumption (Siegrist, 2008). Consumers have to believe in the arguments provided by the food industry (e.g. taste and sensory attributes), scientists (e.g. efficacy of ingredients) and the government (e.g. regulation on food safety). Subsequently, *trust* is an important factor for consumers' evaluation of new food technologies. In the context of acceptance of irradiated food by US consumers, trust in scientists and public health officials had a moderately strong and statistically significant influence on perceived risks (negatively) and acceptance (positively) (Sapp & Downing-Matibag, 2009). Higher levels of trust in governance among Dutch consumers also resulted in a more positive attitude toward GM food and they were more likely to accept it (Gutteling et al., 2006). Transferred to the new technology of 3D food printing, consumers have very few experiences related to 3D printing and especially to 3D-printed food (Brunner et al., 2018). Consumers have to rely on the information provided by several institutions which are important actors in the global food system, i.e. scientists, food safety governmental institutions and food industry. Thus, trust seems to have an influence on perceived benefits, perceived risks and intention to consume 3D-printed food, which allows deducing:

H_{2a}: Trust in institutions has a positive effect on perceived benefits.

H_{2b}: Trust in institutions has a negative effect on perceived risks.

H_{2c}: Trust in institutions is positively related to intention to consume 3D-printed food.

Consumers who perceived a food technology innovation as beneficial exhibit positive evaluations (Henson et al., 2008a). For example, Siegrist et al. (2007) stated that *perceived benefit* by consumers seems to be the most important predictor for willingness to buy food modified by nanotechnology similar to GM food studies (Kim, 2012; Prati et al., 2012). Thereby, perceived benefits can be looked at from different perspectives. Following Ronteltap et al. (2007), benefits can be distinguished between the individual consumer and benefits to the society. Regarding the former, positive health impact (Labrecque et al., 2006; Verbeke, 2005), specific personal quality perceptions of the product, e.g. appearance (Deliza et al., 2010) and especially the naturalness of innovative food (technologies) (Hudson et al., 2015; Román et al., 2017; Ronteltap et al., 2007; Siegrist et al., 2016; Tenbült et al., 2008) are considered key benefits. The latter (more broadly societal benefits) were measured by environmental benefits (Chen, 2008), the necessity of the technology (Henson et al., 2008a) and from an economic (cost-benefit analysis) point of view (Ronteltap et al., 2007). Convenience is an important benefit among consumers with time-constraints (Jabs & Devine, 2006). The developers of 3D food printer are arguing with several benefits which can be clustered to 5 dimensions, i.e.

convenience, naturalness, socio-economic, environment, and health (see Appendix F). Thus, the more consumers perceive the potential benefits of 3D-printed food regarding producing food in a convenient, cost-efficient, environmental-friendly way that is natural and healthy, the more consumer will intend to consume 3D-printed food. Consequently, it is assumed:

H_3: Perceived benefits are positively related to intention to consume 3D-printed food.

Generally, perceived benefits increase the positive evaluation of food technologies whereas *perceived risk* decreases it (Siegrist, 2000). Perceived risks are associated with impact on health, harmful/dangerous, negative impact on environment, cause for concern/worry, unknown/uncertain (Henson et al., 2008a) and are generally having a negative effect on food evaluation among consumers (Kamrath et al., 2019; Lyndhurst, 2009). For example, the purchase probabilities of GM foods in Romania was primarily driven by risk perceptions (Curtis & Moeltner, 2007). Further, risk perceptions played an important role in determining Taiwanese's intention to take precautions to avoid consuming food that contain additives (Chen, 2017). Transferred to the case of 3D-food printing, this technology also provides several disadvantages that can be bunched in 5 dimensions, in accordance with the perceived benefits (see Appendix F). The more consumers perceive risks regarding 3D-printed food, the less likely is that they would consume 3D-printed food. Thus, it is posited:

H_4: Perceived risks are negatively related to consume 3D-printed food.

As a fifth factor influencing intention to consume 3D-printed food, *perceived behavioral control* is included in the model and demonstrated mainly positive relationships to the evaluation of new food technologies (Kamrath et al., 2019). Perceived behavioral control is part of the Theory of Planned Behavior and refers to the resources and opportunities available to a person as well as its confidence to perform the behavior of interest (Ajzen, 1991). According to the literature review by Lusk et al. (2014), literature suggests that a new food technology is perceived as riskier, and is less likely to be accepted, when people do not perceive that they have control over whether they consume the new product. With respect to 3D-printed food, consumers need to have the confidence to print and also eat 3D-printed food for finally consuming 3D-printed food. As stated by developers of 3D food printer, "3D food printing will help consumers to make at home what manufacturers produce in a factory, hence giving them back the control over the process of designing food" (Fougier, 2017). Following the assumption that consumers who feel confidence and control over eating 3D-printed food are more likely to accept it, it is hypothesized:

H_5: Perceived behavioral control is positively related to intention to consume 3D-printed food.

Attitude is defined by Ajzen (1991) as "the degree to which a person has a favorable or unfavorable evaluation of appraisal of the behavior in question". Following this definition, attitude can be replaced by perceived benefits and perceived risks that refers to the perception of the positive or negative consequences of a specific behavior, respectively. Ronteltap et al. (2007) also argues that the attitude construct is more implicitly defined in terms of perceived costs and benefits. *Quality perception of the product* refers to the appearance, taste, naturalness and healthiness (Kamrath et al., 2019). These attributes of a product are part of the perceived benefits and risks, e.g. healthy food by personalized printed 3D food with specific nutrients or the risk of eating artificial food. *Impact on health*, e.g. the insecurity of long-term health effects, is also covered by the health dimension of perceived benefits and risks. Thus, after replacing attitude with perceived benefits and risks, and quality perception of the product and the impact on health being part of the 5 dimensions of perceived benefits and risks, the proposed model comprises 5 factors influencing the intention to consume 3D-printed food, i.e. (1) subjective knowledge, (2) trust in institutions, (3) perceived benefits, (4) perceived risks, and (5) perceived behavioral control (Figure 4.1). The proposed model is also in line with the results of other literature reviews with the aim to identify main socio-psychological factors in order to determine whether a particular food technology will be accepted or rejected (Bearth & Siegrist, 2016; Frewer et al., 2011; Gupta et al., 2012; Lusk et al., 2014; Ronteltap et al., 2007).

4.2.2 Theory of Planned Behavior

Although a new model is justified by the fact that models are best suited to its initial specific behavioral context (Darnton, 2008), making use of established theories is advantageous by its consistency, broad in scope, and parsimony (Mitchell & Jolley, 2007). Therefore, this chapter uses the well-known and in the context of new food technology applied Theory of Planned Behavior. Applying a common model such as TPB (1) provides some other insights to consumers' intention to consume 3D-printed food compared to the proposed FTAM, and (2) enables to compare the explained variance between the two models (TPB and FTAM).

The TPB states that the intention to perform a behavior is the outcome of a rational decision making process that involves considering (1) person's attitudes toward the behavior, (2) the influence of others to do the behavior (subjective norm), and (3) an assessment of a person's ability to perform it (perceived behavioral control) (Ajzen, 1991). Referring to the evaluation of 3D-printed food, it is assumed that (1) a positive evaluation of the food (attitude), (2) a positive

opinion and behavior toward 3D-printed food by important others, e.g. family, friends, colleagues (subjective norm), and (3) the confidence to eat 3D-printed food will influence the intention to consume 3D-printed food (Figure 4.2). Thus, it is posited:

H_6: Attitude toward 3D-printed food is positively related to intention to consume 3D-printed food.

H_7: Subjective norm is positively related to intention to consume 3D-printed food.

H_5: Perceived behavioral control is positively related to intention to consume 3D-printed food. [same as FTAM]

Table 4.1 summarizes the hypotheses of this chapter and Figure 4.1 and Figure 4.2 provides the two research models, including relationships and hypotheses that are analyzed within this chapter.

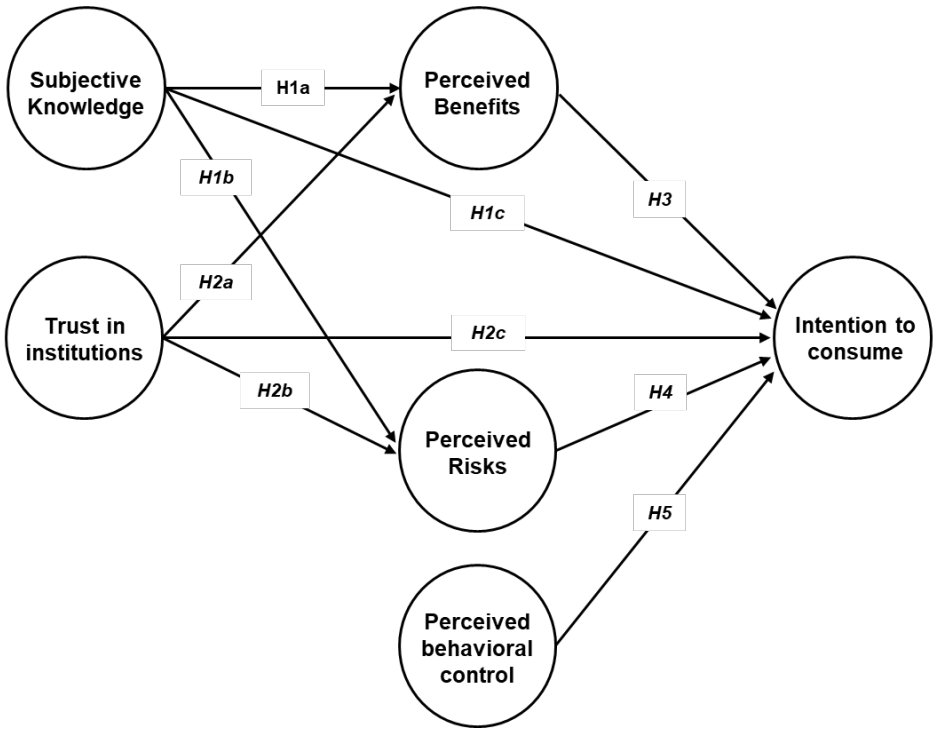

Figure 4.1: Proposed Technology Acceptance Model (FTAM).

Source: Derived from Kamrath et al. (2019).

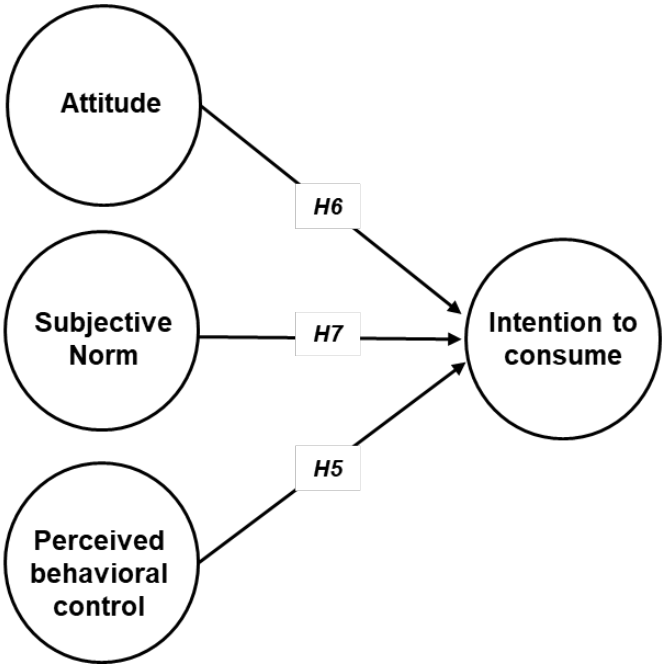

Figure 4.2: Theory of Planned Behavior.

Source: Adapted from Ajzen (1991).

Table 4.1: Hypotheses of research models FTAM and TPB.

Relationship		Hypotheses
		FTAM
SKNOW→PB	H_{1a}	Knowledge has a positive effect on perceived benefits.
SKNOW→PR	H_{1b}	Knowledge has a negative effect on perceived risks.
SKNOW→I	H_{1c}	Knowledge is positively related to intention to consume 3D-printed food.
TRUST→PB	H_{2a}	Trust in institutions has a positive effect on perceived benefits.
TRUST→PR	H_{2b}	Trust in institutions has a negative effect on perceived risks.
TRUST→I	H_{2c}	Trust in institutions is positively related to intention to consume 3D-printed food.
PB→I	H_3	Perceived benefits are positively related to intention to consume 3D-printed food.
PR→I	H_4	Perceived risks are negatively related to intention to consume 3D-printed food.
PBC→I	H_5	Perceived behavioral control is positively related to intention to consume 3D-printed food.
		TPB
A→I	H_6	Attitude toward 3D-printed food is positively related to intention to consume 3D-printed food.
SN→I	H_7	Subjective norm is positively related to intention to consume 3D-printed food.
PBC→I	H_5	Perceived behavioral control is positively related to intention to consume 3D-printed food.

Source: Own illustration.

4.3 Materials and Methods

4.3.1 Sample characteristics

A survey, developed in combination with Qualtrics (www.qualtrics.com), targeted 521 German consumers and was conducted in October 2018. Quotas were used for age and gender to reach a representative sample for Germany. A number of respondents were excluded from the dataset, either their respondents time was less than 7 minutes in total (*N*=14, median 16 minutes) or they selected the same Likert scale response (i.e. 'strongly disagree') for all items within a construct including the ignorance of reversed items (*N*=44). With both data quality criteria, participants with weak attention to the questionnaire were identified, resulting in a total number of 463 consumers for the final dataset.

4.3.2 Measurement of constructs

In developing the survey, a questionnaire and scales were developed, reflecting insights from both social-scientific theories and the extended literature on food technology evaluation research. An overview of the construct definitions is provided in Table 4.2. After assessing the subjective and objective knowledge, consumers were provided with information about 3D food printing, as knowledge about this process is currently low. Further, the questionnaire continued with questions to the included latent variables and closed with details about their socio-demographic data.

For some of the reflective latent variables, validated measures already existed; for others, especially for the perceived benefits and risks, measured had to be developed. Unless otherwise noted, survey items presented 5-point Likert scales from (1) 'strongly agree' to (5) 'strongly disagree' (see Appendix G) and were translated to German.

Independent variables within FTAM – The survey used standard items from the literature to measure subjective knowledge (Flynn & Goldsmith, 1999), trust in institutions (research, government, food industry) at a scale from (1) 'a lot of trust' to (5) 'no trust at all' (Siegrist, 2000), and perceived behavioral control (Ajzen, 2006). The latter was measured on different scales, i.e. (1) 'definitely' to (5) 'never', (1) 'possible' to (5) 'impossible', (1) 'definitely true' to (5) 'definitely false', (1) 'no control' to (5) 'complete control', and (1) 'strongly agree' to (5) 'strongly disagree'. Three questionnaires for each of the 5 dimensions of perceived benefits and risks were developed by statements of extended literature, respectively.

Table 4.2: Definitions of latent constructs within research models FTAM and TPB.

Variable	Construct	Operational Definition
		FTAM
SKNOW	Subjective Knowledge	One's belief what he or she knows about 3D-printed food (based on Flynn & Goldsmith, 1999).
TRUST	Trust in Institutions	An individual's confidence placed to institutions involved in the global food system (research, government, food industry) (based on Siegrist, 2000).
PB	Perceived Benefits	One's perception of the positive consequences that are caused by eating 3D-printed food.
PR	Perceived Risks	An individual's judgement of negative consequences that are caused by eating 3D-printed food.
PBC	Perceived Behavioral Control	An individual's feeling of confidence and control over eating 3D-printed food (adapted from Ajzen, 1991).
I	Intention to consume	An individual's behavioral intention to eat 3D-printed food (adapted from Ajzen, 1991).
		TPB
A	Attitude	The degree to which a person has a favorable or unfavorable evaluation of eating 3D-printed food (adapted from Ajzen, 1991).
SN	Subjective norm	One's perception of whether important others (e.g. family, friends, colleagues) perceive they should eat 3D-printed food (adapted from Ajzen, 1991).
PBC	Perceived Behavioral Control	An individual's feeling of confidence and control over eating 3D-printed food (adapted from Ajzen, 1991).
I	Intention to consume	An individual's behavioral intention to eat 3D-printed food (adapted from Ajzen, 1991).

Source: Own illustration.

Independent variables within TPB – Based on Ajzen (2006), attitude toward the product/technology was assessed with 6 semantic differentials, *beneficial* to *harmful*, *pleasant* to *unpleasant*, *valuable* to *worthless*, *responsible* to *irresponsible*, *wise* to *foolish*, and *positive* to *negative*, each using a 5-point scale. Subjective norm was measured with 6 items on scales from (1) 'yes' to (5) 'no', (1) 'likely' to (5) 'unlikely', and (1) 'strongly agree' to (5) 'strongly disagree' (Ajzen, 2006). Perceived behavioral control can be invoked by both models.

Dependent variable for both models – The final variable in the causal models is intention to consume 3D-printed food. Intention to consume 3D-printed food was assessed with 14 items, asking about their likelihood to consume 3D-printed food when specific benefits are provided by 3D-printed food (e.g. environment, health), or when 3D-printed food is offered in different situations (e.g. by a friend, in a restaurant or supermarket). Finally, the participant was asked to make a decision if he or she intends to eat 3D-printed food (1) yes or (2) no.

Consumer characteristics – With the aim to characterize the participants in the survey, consumers' objective knowledge, innovativeness (Parasuraman, 2000), ecological worldview (Dunlap et al., 2000), and food involvement (Bell & Marshall, 2003) were assessed. For measuring the objective knowledge, participants were asked 10 true-false questions about 3D-printed food developed based on extended literature. This approach was adapted by other studies that assessed consumers' knowledge about food products (Pieniak et al., 2010; Zhang & Liu, 2015), but it has to be noted that true-false answers may contain bias resulting from guessing where knowledge does not exist (Carlson et al., 2009; Zhang & Liu, 2015). Finally, participants were asked for age, gender, educational level, family and employment status, and income.

4.3.3 Data Analysis

Both models were estimated using the structural equation modeling features of SmartPLS 3. The component-based analysis using partial least square estimation (PLS), developed by Wold (1974; 1982; 1985), is a structural path estimation approach combining confirmatory factor analysis (outer model) and regression analysis in one framework (inner model) (Hair et al., 2013). PLS path modeling does not presume any distributional form of measured variables and can estimate complex models with many latent and manifest variables. Due to the variance based approach, PLS-SEM aims rather in exploratory research while finding and debunking effects, explaining variances and testing a model (Henseler et al., 2009). In this chapter, the measurement items are perception-based measured on a Likert scale. Thus, multivariate normal distributed data cannot be assured. Further, the nature of this study is rather exploratory as consumers are confronted with a hypothetical food they have not yet seen or tested.

In sum, PLS-SEM is used for the FTAM with PB, PR and I as endogenous (dependent) and SKNOW, TRUST, PBC as exogenous (independent) variables and for TPB with I as endogenous and A, SN and PBC as exogenous variables. The outer model is determined by reflective measured constructs. The inner model is represented by the direct relationships between latent constructs. SKNOW and TRUST are further considered as having a mediator effect through PB and PR (Hair et al., 2013). According to Hair et al. (2013) based on Cohen (1992), to achieve a statistical power of 80% for detecting minimum R^2 values of 0.10 (with a 1% probability of error), the recommended sample size should exceed 205 observations with a maximum number of arrowheads of 5 pointing on I. Thus, the sample size of 463 observations in this study exceeds the threshold amount.

4.4 Results

4.4.1 The sample

The characteristics of the sample in this study are presented in Table 4.3.

Table 4.3: Descriptive statistics of manifest variables for 3D food printer sample.

		N (total 463)	%
Age	18-24 years	37	8%
	25-34 years	72	16%
	35-44 years	64	14%
	45-54 years	86	18%
	55-64 years	85	18%
	65+ years	119	26%
Gender	female	231	50%
	male	232	50%
Education (highest)	general school education	215	46%
	practical education	130	28%
	academic education	114	25%
	none of them	4	1%
Income (monthly household income)[a]	less than 1,300€	68	15%
	1,301 – 1,700€	69	15%
	1,701 – 2,600€	104	22%
	2,601 – 3,600€	124	27%
	3,601 – 5,000€	70	15%
	more than 5,000€	28	6%
Family status	married	214	46%
	in relationship	67	15%
	single	116	25%
	divorced	50	11%
	widowed	16	3%
Employment	full time	193	42%
	part-time	44	10%
	unemployed	15	3%
	school/study/apprenticeship	38	8%
	housewife/husband	29	6%
	be on a pension	139	30%
	others	5	1%

Remark: Income groups for Germany are based on Destatis (2019).

Source: Own illustration.

In regards to age, 26% of the participants were 65+ years old and only 8% were younger than 25 years. The other age groups were quite equally distributed. Equally 50% male and female

were included in this study. Practical and academic educations were equally distributed whereas general school education was dominating. The majority of participants worked full-time (42%) or was on a pension (30%), hence 27% of household incomes reached 2.601-3.600€/month and 22% reached 1.701-2.600€/month. Respondents were mainly married (46%) or single (25%). These sample distributions represent German population in terms of age and gender. Notably, there are slightly biases with regard to family status, education, and income, i.e. the sample includes less single, more academical educated, however, less earning persons as compared to the German population (Destatis, 2019; Zensus, 2011).

In addition, consumers are characterized regarding their level of food involvement, innovativeness and ecological worldview. Figure 4.3 illustrates the median differences between these three characteristics. The median of the ecological worldview and level of food involvement tends to 2 (‘agree’), indicating a slightly engagement to environmental awareness and food decisions. However, the median of the innovativeness scale incline to 3 (‘neither nor’), demonstrating a rather neutral innovative group of people in the sample.

In total, respondents were more willing to eat 3D-printed food (60% indicated ‘yes’, I would eat 3D-printed food) than refusing it (40% said ‘no’).

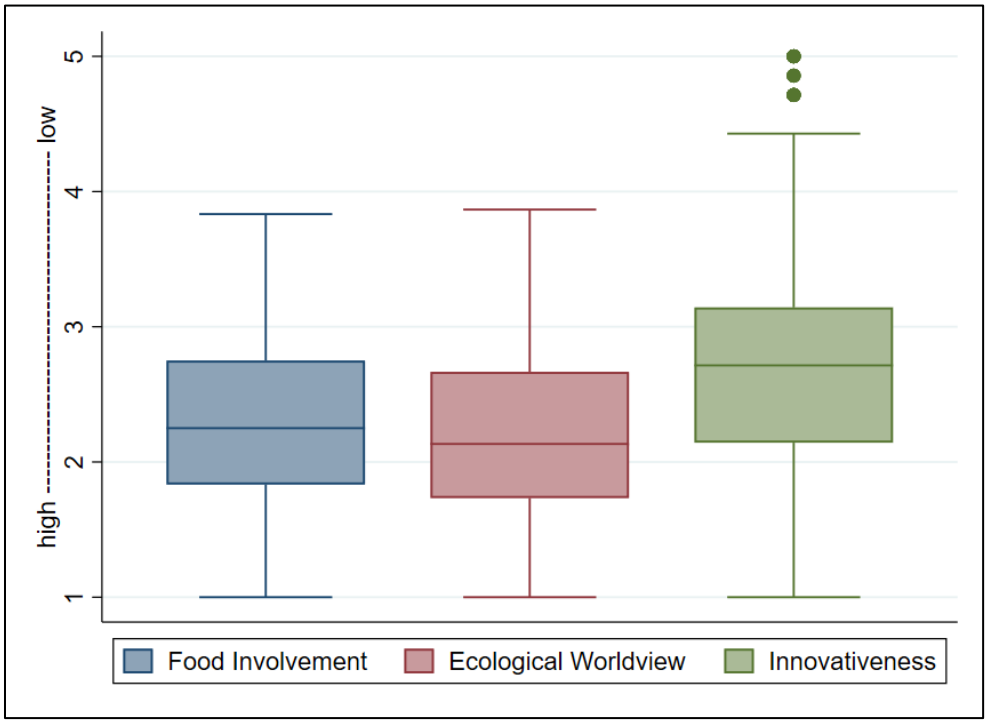

Figure 4.3: Boxplot for consumer characteristics for 3D food printer sample.

Source: Output of Stata.

4.4.2 Knowledge of participants about 3D food printer

In the beginning of the survey, consumers were asked about their perception of their knowledge (subjective knowledge), followed by an assessment of objective knowledge (10 true-false question). The personal assessment of knowledge was rather low (median of subjective knowledge = 4 'disagree') even though the median of right answered true-false-questions was 7 (from total *N*=10), indicating a rather good objective knowledge. Results of the Wilcoxon signed-rank test for the difference between subjective knowledge and objective knowledges confirm the significant lower perceived knowledge assessment by participant compared to the objective knowledge assessment (Table 4.4).

Table 4.4: Wilcoxon signed-rank test for differences between subjective knowledge and objective knowledge scores for 3D food printer sample.

Ranks for SKNOW – OKNOW				**Statistic for Test[a]**	
	N	**Sum of Ranks**	**Expected**		**PDI-DS – PDI-OF**
Positive Ranks	16[a]	1937	53144	Z	-17.930
Negative Ranks	400[b]	104351	53144	Prob > | z |	0.0000
Ties	47[c]	1128	1128	a. Wilcoxon Signed Ranks Test	
Total	463	107416	107416		
a. SKNOW > OKNOW b. SKNOW < OKNOW c. SKNOW = OKNOW					

Remark: SKNOW=Subjective knowledge, SKNOW scores=summed score, 1=Perceived no knowledge; 5=Perceived high knowledge); OKNOW=Objective knowledge, OKNOW scores=sum of true-false questions.

Source: Output of Stata.

4.4.3 Evaluation of reflective measurement models

The PLS-SEM algorithm could find a stable solution within 7 iterations. Different indicators were used to assess the reliability and validity of the outer models for TPB and FTAM (Table 4.5).

Convergent validity – Convergent validity, showing if items are measuring the same construct converge or share a high proportion of variance in common (Hair et al., 2014), was assessed by the outer loadings and the average variance extracted (AVE). The data shows convergent validity problems as some factor loadings did not meet the threshold of 0.708 of outer loadings (Hair et al., 2013) and the AVE value for the PBC construct did not exceed the threshold of 0.5 (Table 4.5).

Internal consistency reliability – Measuring the interrelation between indicators (internal consistency reliability) is done by Cronbach's alpha and the composite reliability, and both should meet the threshold of at least 0.7 for a satisfactory level (Hair et al., 2014). PBC shows internal consistency reliability problems (Table 4.5).

Table 4.5: Results summary of reflective measurement models for FTAM and TPB.

Variables	Number of items	Cronbach's alpha[a]	Composite reliability[a]	AVE[b]
		FTAM		
Subjective knowledge	6	0.813	0.863	0.526
Trust in institutions	7	0.867	0.898	0.558
Perceived benefits	15	0.950	0.956	0.594
Perceived risks	15	0.938	0.945	0.538
Perceived behavioral control	7	0.464	0.641	0.309
Intention to consume	14	0.943	0.952	0.595
		TPB		
Attitude toward 3D-printed food	6	0.944	0.956	0.782
Subjective norm	6	0.881	0.912	0.641
Perceived behavioral control	7	0.464	0.641	0.309
Intention to consume	14	0.943	0.952	0.595

Remark: [a] Treshold ≥ 0.7; [b] AVE=Average variance extracted, treshold ≥ 0.5 (Hair et al., 2013).

Source: Own illustration of Smart-PLS 3 output.

Discriminant validity – Discriminant validity indicates whether one latent construct is truly distinct from other latent constructs (Hair et al., 2014) and is measured by the Fornell-Larcker Criterion and the Heterotrait-Monotrait Ratio (HTMT). As the square root of PBC's AVE is smaller than its highest correlation within the same construct and the HTMT value exceeds 0.85 indicating a correlation close to one (Henseler et al., 2015), PBC has a clear discriminant validity problem (Table 4.6). An exploratory factor analysis showed that PBC items loaded on the same factor as intention items, following that PBC is not truly distinct from intention.

For treating discriminant validity problems, Henseler et al. (2015) suggested specific guidelines, i.e. eliminating items that are strongly correlated with items in the opposing construct. Although respective items were deleted, the discriminant validity between PBC and I was not established. The other approach to treat discriminant validity problems would suggest merging PBC and I into a more general construct (Henseler et al., 2015) but both constructs are theoretically differently defined (Ajzen, 1991) and discriminant validity was established throughout various studies (e.g. Armitage & Conner, 2001; Riebl et al., 2015). Nevertheless, it seems that consumers did not distinguish between both constructs. Consequently, the PBC

construct had to be deleted from both models to achieve reliable and valid constructs. In order to meet all thresholds, especially for outer loadings, further some items of TPB (I08, I10^{r}, I14, SN03, SN06^{r})[16] and FTAM (I08, I10^{r}, I14, PB01ec, PB03h, PR01c, PR01ec, PR02c, PR03c, PR03ec, SKNOW02^{r}, SKNOW05^{r} and SKNOW06^{r}) had to be deleted. Deleting PBC from TPB results in the Theory of Reasoned Action (TRA).

Table 4.6: Discriminant validity criteria for FTAM and TPB.

FTAM

	Intention to consume	**Perceived Behavioral Control**	**Perceived Benefits**	**Perceived Risks**	**Subjective Knowledge**	**Trust in Institutions**
Intention to consume	0.771					
Perceived Behavioral Control	0.766 *(0.873)*	0.555				
Perceived Benefits	0.714 *(0.748)*	0.621 *(0.711)*	0.771			
Perceived Risks	-0.570 *(0.587)*	-0.552 *(0.631)*	-0.607 *(0.633)*	0.733		
Subjective Knowledge	0.400 *(0.423)*	0.396 *(0.574)*	0.417 *(0.436)*	-0.173 *(0.214)*	0.725	
Trust in Institutions	0.607 *(0.667)*	0.531 *(0.700)*	0.572 *(0.622)*	-0.426 *(0.455)*	0.260 *(0.283)*	0.747

TPB

	Attitude	**Intention to consume**	**Perceived Behavioral Control**	**Subjective Norm**
Attitude	0.884			
Intention to consume	0.714 *(0.750)*	0.771		
Perceived Behavioral Control	0.638 *(0.765)*	0.766 *(0.873)*	0.555	
Subjective Norm	0.650 *(0.700)*	0.768 *(0.822)*	0.696 *(0.821)*	0.800

Remark: Treshold for Fornell-Larcker Criterium (standard) to indicate discriminant validity: √AVE > correlation with other constructs; Heterotrait-Monotrait Ratio (HTMT) *(italic)* ≥ 0.85 (Hair et al., 2013).

Source: Own illustration of Smart-PLS 3 output.

[16] ^{r} = reversed coding.

4.4.4 Assessment of overall structural model

In a second step, the structural equation models were evaluated by the PLS method. Therefore, Figure 4.4 and Figure 4.5 illustrate the model results of the proposed FTAM and TPB, respectively. The significance of path coefficients was assessed by the bootstrapping procedure with 5,000 subsamples and a significance level of 0.05 on the basis of a two tailed test.

Multicollinearity assessment – Denying the negative affect by collinearity, variance inflation factor (VIF) values should be below 5 (Hair et al., 2013). In this study, values ranged from 1.088 (TRUST→PR, TRUST→PB) to 2.220 (PB→I) for FTAM, reporting no problem for multicollinearity. This also holds true for TRA constructs with 1.734 (A→I, SN→I).

Coefficient of variance (R^2) – When R^2 values of endogenous constructs exceed the thresholds of 0.75, 0.50 and 0.25, latent constructs have substantial, moderate and weak explanatory power (Hair et al., 2014). For TRA, I has a moderate R^2-value (0.663) and for FTAM, R^2 values of PR (0.185) indicates weak explanatory power, PB (0.409) nearly moderate and I (0.589) moderate explanatory power. Thus, the moderate R^2-value of I within TRA is higher than the one of FTAM.

f^2 effect size – Using the f^2 effect size, the impact of an exogenous construct on the endogenous construct was assessed. According to Hair et al. (2013), f^2 values of 0.02, 0.15 and 0.35 represent small, medium, and large effects of the exogenous latent variables, respectively. Thus, I within TRA is medium effected by A (0.234) and large effected by SN (0.470). For FTAM variables, PB (0.137), PR (0.079), SKNOW (0.023) and TRUST (0.124) have a small effect on I. TRUST (0.363) has a large effect on PB but SKNOW (0.143) has only a moderate effect on PB. PR is impacted with a medium effect by TRUST (0.191). However, SKNOW (0.003) has no effect on PR.

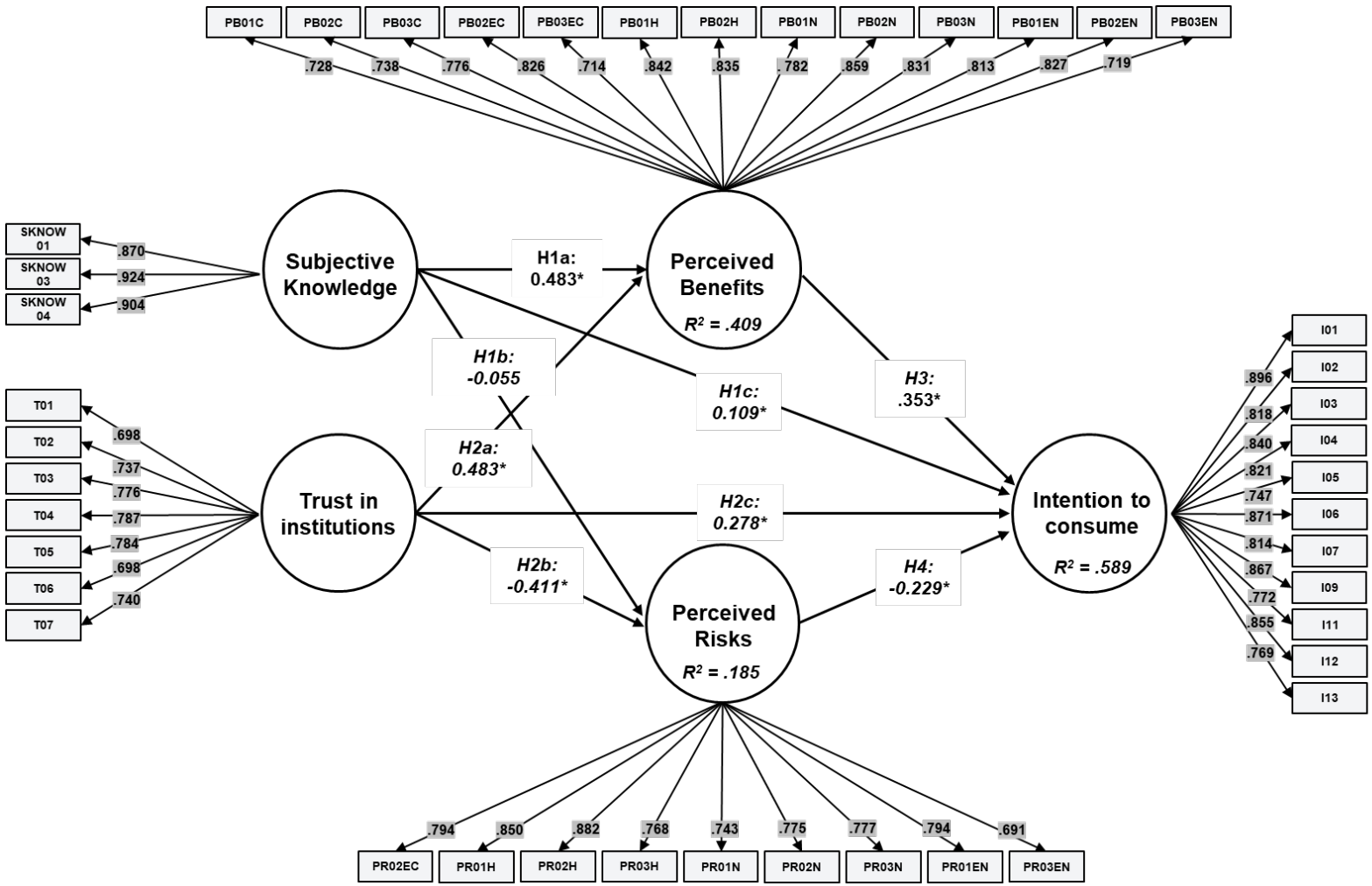

Figure 4.4: PLS path coefficients and bootstrap statistics for FTAM.

Remark: * = *p*-value (0.000); R^2-values ≥ 0.75, 0.5, 0.25 indicate substantial, moderate and weak explanatory power; PLS-SEM with maximum 5,000 iterations and stop criterion at 10^{-7}.

Source: Own illustration based on SmartPLS output.

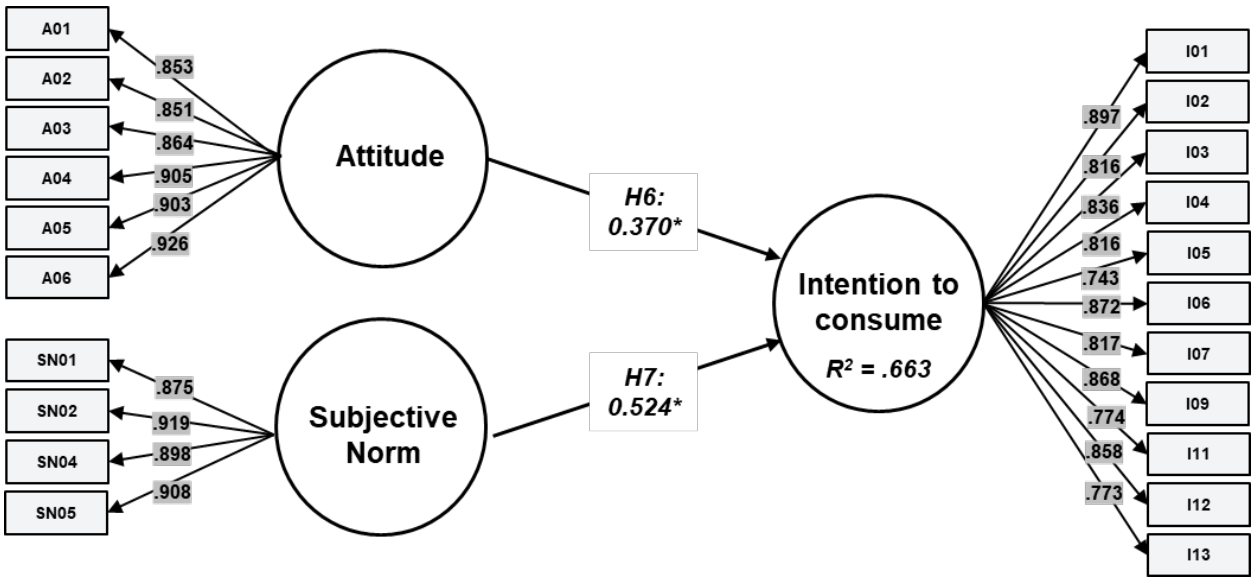

Figure 4.5: PLS path coefficients and bootstrap statistics for TRA.

Remark: * = *p*-value (0.000); R^2-values ≥ 0.5 indicate moderate explanatory power; PLS-SEM with maximum 5,000 iterations and stop criterion at 10^{-7}.

Source: Own illustration based on SmartPLS output.

Cross-validated redundancy (Q^2) – Applying the blindfolding procedure, the Stone-Geisser's Q^2 value is calculated for reflective items. The Q^2 value indicates model's predictive relevance for values larger than zero, whereas Q^2 smaller than zero represents a lack of predictive relevance (Hair et al., 2013). The Q^2 of all endogenous constructs I (0.418) for TRA as well as I (0.372), PB (0.239) and PR (0.107) for FTAM have larger values than zero, which implies that both models have predictive relevance for the respective constructs.

The path coefficients and hypotheses testing – Since PBC was deleted from the models due to reliability and validity problems, H_5 cannot be analyzed (Figure 5, Figure 6). For TRA, both exogenous constructs A (0.370, *p*= .000) and SN (0.524, *p*= .000) have strong positive influences on I, hence, H_6 and H_7 cannot be rejected. Regarding the proposed FTAM, considering first the exogenous construct SKNOW, hypotheses H_{1a} and H_{1c} cannot be rejected, indicating the higher SKNOW the more positive participants evaluated PB of the technology and the higher was the intention to eat 3D-printed food. However, SKNOW had no significant influence on PR. Thus, H_{1b} is rejected.

Regarding the exogenous construct TRUST, all hypotheses H_{2a}, H_{2b} and H_{2c} show significant results, demonstrating a positive influence of TRUST on PB and I as well as a negative effect on PR. Further, PB increases the likelihood of I, whereas PR negatively effects I. These hypotheses (H_3 and H_4) show strong relationships between constructs (H_3: 0.353, *p*= .000;

H_4: -0.229, *p*= .000). Further, results show that PB complementary (partial) mediates[17] the effect of TRUST to I as well as SKNOW to I. PR complementary (partial) mediates the effect of TRUST to I but not SKNOW to I. The latter has only a significant direct effect between SKNOW and I.

4.4.5 Socio-economic influences

In the previous analysis, it was assumed that the cause-effect relationships in the PLS path model are direct effects without any systematic influences of other variables. However, it is likely that respondents are heterogeneous in their perceptions and evaluations of latent variables, yielding in significant different path coefficients across two or more groups of respondents (Hair et al. 2013). To find out whether there is a significant difference between coefficients, a PLS-SEM multigroup analysis (PLS-MGA) was run for all dummy variables, i.e. gender, willingness to consume 3D-printed food (yes/no), food involvement (high/low), ecological worldview (high/low) and innovativeness (high/low).

The parametric approach of PLS-MGA shows that most of the relationships between latent variables do not differ significantly throughout the different dummy variables. In Table 4.7 all 9 significant differences are presented. For gender, it was found that female respondents had a stronger relationship between TRUST and PB as well as between SKNOW and PB than male respondents. Respondents who scored higher on the ecological worldview scale had a stronger negative relationship between TRUST and PR than those who scored lower. Further, people with a lower ecological worldview had no significant effect between SKNOW and PR, however, a significant negative relationship was found for respondents with an higher ecological worldview. When looking at high food involved respondents, they had a significant negative relationship between SKNOW and PR but low food involved participants had no significant relationship. For respondents who were not willing to consume 3D-printed food and are less innovative, the relationship between SKNOW and I was positive and significant. The respective other group of these dummy variables showed no significant results. Innovativeness is an interesting grouping variable for the association of PB and I as well as of PR and I. Innovative people had a stronger positive effect of PB on I but a weaker negative effect of PR on I than less innovative respondents. Thus, innovative people evaluated PB as more positive and PR as less negative than less-innovative people.

[17] Mediation analysis procedure follows Zhao et al. (2010).

Table 4.7: Results of multi group analysis in PLS-SEM for FTAM.

Relationship	Dummy variable		Path coefficients		PLS-MGA Parametric Test		
in PLS-SEM	**type**		**coefficient**	***p*-value**	**path coefficients difference**	**t-value**	***p*-value**
TRUST→PB	gender	male	0.248	0.000	0.180	2.512	0.012
		female	0.310	0.000			
TRUST→PR	ecological worldview	high	-0.459	0.000	0.161	1.823	0.069
		low	-0.298	0.000			
SKNOW→PB	gender	male	0.246	0.000	0.133	1.954	0.051
		female	0.379	0.000			
SKNOW→PR	food involvement	high	-0.217	0.000	0.285	3.101	0.002
		low	0.068	0.350			
	ecological worldview	high	-0.228	0.000	0.313	3.447	0.001
		low	0.085	0.266			
SKNOW→I	willingness to consume	yes	0.036	0.482	0.237	2.775	0.006
		no	0.273	0.000			
	innovativeness	high	0.032	0.495	0.140	2.165	0.031
		low	0.171	0.000			
PB→I	innovativeness	high	0.461	0.000	0.238	2.420	0.016
		low	0.223	0.001			
PR→I	innovativeness	high	-0.144	0.006	0.198	2.633	0.009
		low	-0.342	0.000			

Remark: TRUST=Trust in institutions; SKNOW=Subjective knowledge; PB=Perceived benefits; PR=Perceived risks; I=Intention. Dummy variables for ecological worldview, food involvement and innovativeness created based on the respective median.

Source: Results based on PLS-MGA output.

With specific focus on the intention to consume 3D-printed food, the role of socio-economic characteristics (age, gender, education, income, food involvement, ecological worldview and innovativeness) are investigated by applying the non-parametric Kruskal-Wallis-Test (Table 4.8). Results show that younger, male, academical educated, who have higher income, a lower ecological worldview, are more involved in food, and more innovative are more willing to consume 3D-printed food than the respective opposite group.

Table 4.8: Kruskal-Wallis-Test for consumer characteristics and intention to eat 3D-printed food for FTAM.

		Willing to eat - yes	**Ranks**		**Test Statistics for grouping variable and intention[a]**		
Grouping variable	Group definitions	N (% per group)	N (total)	Rank Sum	Chi-squared[b]	df	Asymp Sig.
Age [in years]	18-24	29 (78%)	37	7013.50	31.832	5	0.000
	25-34	53 (74%)	72	14442.50			
	35-44	45 (70%)	64	13326.50			
	45-54	54 (63%)	86	19405.00			
	55-64	48 (56%)	85	20423.00			
	65+	49 (41%)	119	32805.50			
Gender	male	154 (67%)	231	50050.00	8.412	1	0.004
	female	124 (53%)	232	57366.00			
Highest education	general school education	121 (56%)	215	51753.50	8.952	3	0.030
	practical education	73 (56%)	130	31330.50			
	academic education	82 (72%)	114	23311.00			
	none of them	2 (50%)	4	1021.00			
Income (monthly)	less than 1,300€	29 (43%)	68	18514.50	14.195	5	0.014
	1,301 – 1,700€	37 (54%)	69	17033.50			
	1,701 – 2,600€	64 (62%)	104	23768.00			
	2,601 – 3,600€	82 (66%)	124	27021.00			
	3,601 – 5,000€	46 (66%)	70	15321.00			
	more than 5,000€	20 (71%)	28	5758.00			
Food involvement	high involvement	149 (64%)	232	51578.50	3.381	1	0.067
	low involvement	129 (56%)	231	55837.50			
Ecological worldview	high ecological worldview	127 (54%)	236	58155.50	7.770	1	0.005
	low ecological worldview	151 (67%)	227	49260.50			
Innovativeness	more innovative	173 (70%)	248	51958.50	20.964	1	0.000
	less innovative	105 (49%)	215	55457.50			

Remarks: [a] Measured by binary item "Will you eat 3D-printed food? (Yes; no)"; [b] Chi-squared (with ties).

Source: Own illustration based on Stata output.

4.5 Discussion, implications and limitations

In this chapter, the objectives were examined by using quantitative data collected via a survey with German consumers and applying variance based PLS-SEM to assess path coefficients and determine the explanatory power of the variables included in both applied models. This chapter not only makes a theoretical contribution as far as the development of an integrative theory that is relevant for future food technology evaluation research, but also builds upon the current understanding of consumers' evaluation of 3D-printed foods. In this manner, this study

is the first to apply the Food Technology Acceptance Model while also comparing it to the Theory of Planned Behavior. The discussion will address both contributions and its findings in separate sections.

4.5.1 Evaluation of the models' predictive relevance

In this chapter, a proposed Food Technology Acceptance Model (FTAM) was developed based on a systematic literature review by Kamrath et al. (2019) and compared it to the well-known and often applied Theory of Planned Behavior (TPB). Whereas TPB suits to a variety of behavioral analysis throughout different disciplines, FTAM is especially developed for food technology evaluation.

The FTAM and TPB differ in their propositions concerning the factors determining the intention building process. Generally speaking, the TPB is more parsimonious. It suggests that attitude, subjective norm, and perceived behavioral control describe the influence on behavioral intention. FTAM replaces attitude with two mediators (perceived benefits and perceived risks) mediating the effect of subjective knowledge and trust on intention. In addition, perceived behavioral control is included as a direct factor on intention to explain the variance of the outcome variable behavioral intention. Whereas TPB is widely used through different disciplines, FTAM with its full complexity of the framework have not been tested up to this point. The model development is based on strong theoretical foundation by an extensive literature review. Further, the framework supports and extends the 'mind model' developed by Ronteltap et al. (2007) who substantiated it with existing studies. Although, it can argued that the FTAM as a proposed model to determine consumers' evaluation of new food technologies and food innovations is theoretically determined, it requires comprehensive empirical tests.

By taking 3D food printing as a case of new food technologies, both models were applied to assess the explanatory power in shaping consumers evaluation of new food technologies. Although suggested guidelines by Henseler et al. (2015) for treating discriminant validity problems were utilized, the discriminant validity between PBC and I could not be established. Consequently, PBC was excluded from both models. According to Tarka (2018), when the initial model does not (completely) confirm the theory, two conclusions can be drawn, i.e. "proving that either the theory is wrong or that the material (empirical data) on the basis of which the SEM model was constructed is of poor quality." As the significant relationship between PBC and I was demonstrated in previous research, especially in the context of GM food (Cook et al., 2002; Kim et al., 2014; Lu & Gursoy, 2016; Spence & Townsend, 2007), it is assumed that consumers perceived high similarities between both constructs. Consequently, further empirical assessments of the initial proposed framework in the context

of new food technology evaluation would be of high interest. This would allow for further validity checks, so that the involved assumptions become more reliable and valid, and thus, applicable to a range of different research settings within food technology evaluation.

When deleting PBC from the TPB, the final model results in the TRA. The TRA and FTAM models showed good model prediction as demonstrated by relevant R^2, f^2 and Q^2-values. Therefore, the proposed assumptions are in agreement with the obtained empirical data (Tarka, 2018). Although TRA includes only 2 direct predictors on intention, the former explained 66.3% of the variance in intention to consume 3D-printed food, as compared to FTAM, which predicted 58.9% of the variance. Due to the more comprehensive model FTAM compared to the parsimonious TRA, it was expected that the explained variance for intention to consume would be higher for FTAM than for TRA. It can be argued that the dominant role of subjective norm (large effect size) in TRA, i.e. the influence of others opinions and behavior in the context of highly innovative food products, exceeds the explanatory outcome of FTAM factors. This suggests adding subjective norm to FTAM in order to increase the explanatory power.

In conclusion, both models have good model prediction, even after PBC had to be excluded. Whereas TRA/TPB gives insights to new food technology evaluation from a general behavioral background, FTAM is developed especially for the case of new food technology evaluation. In general, using common models has the advantage to make research results comparable. Due to the long-term research focus of new food technology evaluation analyzed with a variety of different models, the FTAM could enable the comparison of consumers' evaluation across various food technologies.

4.5.2 Understanding of consumers' evaluation toward 3D-printed food

The study analyzed several factors within two models. This section discusses the outcomes structured according to the individual factors.

Knowledge – Even though consumers perceived their own knowledge as rather low, the responses to 10 true-false questions indicated a moderate to good objective knowledge. Thus, consumers knew more than they thought they do. This indicates that consumers may regard 3D printing as more complicated as it actually is. Compared to results of other studies on consumers' evaluation of 3D-printed food which reported limited consumers' knowledge (Brunner et al., 2018; Lupton & Turner, 2018), the participants in the study had slightly more knowledge. Aside from contextual differences, like sampling and study location, the possible gain in knowledge could be explained by the time lapse between studies (Lupton and Turner in 2016, Brunner et al. in 2017).

In line with the results by Brunner et al. (2018) that indicate a positive relationship between knowledge and attitude, subjective knowledge positively influenced the intention to consume 3D-printed food. This was especially the case for participants who were willing to consume 3D-printed food and scored high on the innovativeness scale (i.e. they were more innovative than others). Moreover, when comparing high to less innovative people, the former have a stronger relationship between subjective knowledge and perceived benefits, but a weaker relationship between subjective knowledge and perceived risks. As such, this might indicate that higher innovative people are likely to have higher knowledge, and in turn, are better aware about the potential benefits of a new food technology. Further, more knowledge might indicate to evaluate perceived risks more objectively, instead of being driven by fears and uncertainties based on poor knowledge (Brunner et al., 2018). This corresponds with the proposed characteristics of innovators or early adopters by Rogers (1995) which displays a greater knowledge about the technology by innovative people. Furthermore, the results indicate that subjective knowledge is not related to perceived risks, except for people with higher ecological worldview and higher food involvement, where a significant negative relationship was observed. This might be explained by the supported relation between involvement and information-seeking behavior, and thus, higher involved people are more likely to build stronger mind sets about new foods and its technologies. Individuals with a strong ecological worldview are likely to consider direct and indirect consequences of their decisions, also known as system thinking (Meadows, 2008).

Trust in institutions – It is significant associated with perceived benefits and risks and also, though to a smaller extend, to intention to consume 3D-printed food. The large effect of trust in institutions on perceived benefits is stronger for women than for men. This contradicts with the study of Siegrist (2000) about the acceptance of gen technology in food, where gender did not affect the influence of trust in institutions on benefits. Nevertheless, women often play the role of nurturer and care provider at home in the family (Siegrist, 2000), and thus, may be more sensitive to food related topics. As such, women seem to rely more on the information provided by institutions, which are important actors in the global food system, and have a more positive judgement as with increasing knowledge. Further, the negative relationship between trust in institutions and perceived risk is stronger for individuals with higher ecological worldview, in line with results of Siegrist (1999).

Perceived benefits and perceived risks – The two constructs are relevant predictors of the intention to consume 3D-printed food. Both show direct significant effects, but are also mediating the relationship between subjective knowledge and trust in institutions on intention, respectively. For more innovative individuals, the intention to consume 3D-printed food was stronger influenced by perceived benefits and less by perceived risks. These results confirm

other studies, in which innovative people are characterized as risk takers (Dobre et al., 2009), who are likely to deal with inconvenience factors related to the product complexity or lack of performance because they focus on the long-term benefits of the innovation (Faiers & Neame, 2006).

Attitude and subjective norm – Regarding the TRA/TPB, attitude toward 3D-printed food had a medium and subjective norm a large effect on the intention to consume 3D-printed food. It highlights the importance to investigate the social environment and its social pressure of food decisions and behavior.

Consumer characteristics – Furthermore, results indicated that consumer characteristics such as being young, male, academical educated, innovative, being higher involved with food and having higher income were positively related to the intention to consume 3D-printed food. In addition, results pointed out, that consumers with a lower ecological worldview were more likely to consume food made from 3D printer. Consequently, it can be deduced that consumers are not aware of the possible environmental advantages of 3D food printer since other studies revealed that environmental concerns about food choices by consumers increased the interest in alternative novel food products (Verbeke, 2015).

Comparing the results of the FTAM and TRA outcomes in the context of consumers' evaluation toward 3D food printer, relationships between factors are similar to the evaluation of other new food technologies (Brunner et al., 2018; Lusk et al., 2014; Rollin et al., 2011; Ronteltap et al., 2007). For example, consumers having trust in institutions showed a positive evaluation of new food technologies such as functional food (Siegrist et al., 2008a) or irradiated food (Sapp & Downing-Matibag, 2009). In addition, in the case of GM food, a similar relationship was observed, i.e. having a skeptical view of biotechnology companies decreased the likeliness to consume GM foods compared to consumers who trusted biotechnology companies (Onyango & Nayga, Jr., 2004).

4.5.3 Limitations and future research

This chapter provides the first application of a proposed Food Technology Acceptance Model. It contributes to the limited research on 3D-printed food evaluation. Nevertheless, this chapter has some limitations.

Due to the first application of the Food Technology Acceptance Model in this chapter, the validity checks are limited to the case of 3D food printer and a German consumer sample. Thus, its final development will require more effort. Hence, future work should investigate its

relevance for various technologies. Although the tested and valid scale for perceived behavioral control by Ajzen (1991) was used, no significant difference between intention and perceived behavioral control was found, indicating a lack of discriminant validity. Forthcoming work should examine the role of perceived behavioral control.

Moreover, future research should consider and examine the role of subjective norm in a potential Food Technology Acceptance Model, because it was highly important for predicting intention to consume 3D-printed food in the TRA. In this regard, it would be of interest to analyze how subjective norm and trust in institutions are related to each other. This is because both variables are influencing factors from the social and macro-level environment of the individuals' decision setting (Bronfenbrenner, 1979) and are factors that measure influences from the outer environment of the individual.

As shown by the PLS-MGA results within this study, consumer characteristics such as innovativeness, ecological worldview and food involvement are influencing the relationships between factors. Connecting to this analysis, the interaction between these characteristics, e.g. food involvement and ecological worldview, might be interesting to explore in future work. Moreover, by means of a cluster analysis, different types of consumers could be identified. Hence, the variable system thinking should be considered to characterize consumers, especially in regard to evaluate the various benefits and risks of 3D food printer.

Ex-ante research on the evaluation of new food technologies mainly applied cross-sectional designs, which limit its explanatory power. Thus, future studies should consider experimental designs to add on current understanding of consumers' evaluation research on 3D-printed food. Applying between-group designs, experiments offer the possibility to include treatments varying information about benefits of 3D printing regarding convenience, naturalness, economic, environment, health dimensions. Thus, effects of different types of information on consumer' evaluation can be detected. In addition, discrete choice modeling could be considered to identify the effects of different product attributes of 3D-printed food on consumer evaluation. For example, a possible set up could be to vary attributes such as 'food is 3D-printed' (yes/no), 'contains personalized nutritional additives' (yes/no), and 'location of consumption' (home/restaurant).

4.6 Conclusion

In this chapter, a novel theory based framework is introduced that combines variables from extensive literature to explain food technology evaluation behavior and compare it to the Theory of Planned Behavior in the case of 3D-printed food. Both (modified) theories contribute to the understanding of the intention to consume 3D-printed food among German consumers.

Important predictors for the intention to consume 3D-printed food are knowledge, trust in institutions, perceived benefits and perceived risks as well as subjective norm. First, consumers of 3D-printed food can be characterized as young, male, academical educated, and earning high income. They are innovative, more involved in food topics but less environmental responsible. Thus, results show a need for trustworthy information about the applications and opportunities of 3D food printing as it is an important factor influencing the willingness to consume 3D-printed food, and indicate that consumers may seek information from the experience of personal acquaintance in their social networks. The data in this chapter highlight the importance of first addressing early adopters with a well-designed information campaign for a successful implementation of 3D food printers.

Information campaigns to enhance technology adoption are likely more successful with consumers who are involved in food-related topics, as they usually seek more information. Thus, it is needed to understand what drives involvement. Consumers' involvement may differ due to several foci and various scales. While this chapter applied the food involvement scale by Bell & Marshall (2003) in order to measure how close the consumer is with food and food habits, the next chapter investigates the purchase decision involvement scale developed by Mittal (1989a) on the example of dietary supplements.

5 Consumers' involvement and purchasing motives of dietary supplements

Chapter 5 answers Research Question 4 and its respective sub-questions:

RQ 4: What determines consumers' evaluation toward new food technologies exemplified on dietary supplements?

RQ 4.1: To what extent are dietary supplements subject to a higher level of involvement than 'ordinary food' products?

RQ 4.2: Which factors represent potential determinants of consumer involvement in dietary supplements?

This chapter is based on the following publication:

Kamrath, C.; Bidkar, S.; Bröring, S. (2019): Involvement and purchasing motives of dietary supplements. A consumer study from Germany. *PharmaNutrition 9:* 100157. DOI: 10.1016/j.phanu.2019.100157.

5.1 Introduction

The previous chapter showed that food involvement increases the intention to consume new food products (chapter 4). In general, involvement is an important construct to elaborate consumer behavior in the context of food products (Kröber-Riel et al., 2009) since involved consumers are likely to read information provided by the food industry or policymakers which increases the effectiveness of information strategies. Thus, it raises the question what involvement is and what it is triggered by.

The concept of involvement can be explained as the amount of cognitive arousal and interest that consumers demonstrate while making specific purchase decisions (Kröber-Riel et al., 2009). Traditionally, food was considered to be a typical low-involvement product (Laurent & Kapferer, 1985; Zaichkowsky, 1985; Zaichkowsky, 1987) as habitual behavior is pervasive. In this context, the duration of the decision-making process tends to be short. Consumers gather information passively and only invest a limited degree of cognitive effort (Trommsdorff, 2011). They associate certain values with specific products (Mittal & Lee, 1989), which influence their involvement in the purchasing decisions of these products. These values could be utilitarian (i.e. economic, rational, functional goals), sign (i.e. social, self-concept related, or impression management goals) and hedonic (i.e. sensory pleasure or experiential goals).

Hence, the level of involvement is contingent from the individual perception toward those values but could be specified with regard to different types of food. Food is defined by the General Food Law Regulation in the European Union (EU)[18] rather broad, with both ordinary food products as well as dietary supplements are considered to be food. The latter are presented to the consumers not in a traditional food format but rather in a pill or powder format (Bröring, 2005; European Commission, 2002). Thus, dietary supplements are considered to be food with the

> *"purpose of which is to supplement the normal diet and which are concentrated sources of nutrients or other substances with a nutritional or physiological effect, alone or in combination, marketed in a dose form, namely forms such as capsules, pastilles, tablets, pills and other similar forms, sachets of powder, ampoules of liquids, drop dispensing bottles, and other similar forms of liquids and powders designed to be taken in measured small unit quantities where 'nutrients' means the following substances: (i) vitamins, (ii) minerals"* (European Commission, 2002a, Directive 2002/46/EC, Article 2).

However, dietary food supplements are no medical products that claim to restore, correct or modify the body's physiological functions (European Commission, 2002a). However, they do offer additional health benefits to consumers that go beyond basic nutrition. These 'extra' health benefits are credence attributes that cannot be observed by consumers before or after

[18] 'Food' (or 'foodstuff') is defined by the General Food Law Regulation in the European Union (EU) as "any substance or product, whether processed, partially processed or unprocessed, intended to be, or reasonably expected to be ingested by humans", European Commission (2002).

purchasing the product (Darby & Karni, 1973). Several studies have confirmed that 'health' influences higher consumer involvement in products (Arora, 1982; Eertmans et al., 2005; Sarmugam & Worsley, 2015; Verbeke et al., 2007; Verbeke & Vackier, 2004).

In general, the topic of consumer involvement seems to be dynamic, and the specific concept of 'involvement' cannot be measured directly (Laurent & Kapferer, 1985). Consumer involvement in the specific context of food and dietary supplements is a multifaceted topic that demands in-depth study due to several reasons like their appearance, dosage, and primary functionality (Khedkar et al., 2017). Although food and dietary supplements are regulated under the same umbrella, their primary functionalities differ. The main function of food is fulfilling the basic needs of nutrition and health along with sensory aspects like aroma, taste and texture. On the other hand, dietary supplements serve the purpose of meeting specific dietary and health requirements which can be preventive or even at times curative in nature (e.g. to cure vitamin deficiencies). Thus, dietary supplements may not be specifically consumed to fulfil sensory aspects like aroma, taste and texture. They may be perceived as rather medicine due to their pharma-like appearance (e.g. in powder or pill format) and dosage (Khedkar et al., 2017). Along with these factors, the dietary supplement format (i.e. pill or powder) and ingredients may influence consumers' involvement in these products (Homer and Mukherjee, 2018). This implies that consumers may seek certain specific dietary supplements in addition to their usual daily food consumption to meet health needs that are not satisfied solely by ordinary food products. Due to the credence attributes of dietary supplements, consumers may require higher cognitive effort and a longer, more active search for information. This may enable them to comprehend complex product information like nutritional, physiological effects or health claims and take effective purchasing decisions (Hansen et al., 2010; Noor et al., 2014). Therefore, although consumers' involvement in ordinary food products may be high, their involvement in dietary supplements may be even higher. In this regard, motives like consumers' health status could determine their involvement (and potentially its degree) in obtaining health benefits from specific products through their dietary choices. Consumers may perceive typical low involvement products to require high involvement (Paladino, 2005) based on their associated values.

Knowledge about involvement levels of different food categories such as ordinary food and dietary supplements appears to be limited. In addition, research lacks on the understanding which (psychological) factors determine consumer involvement of dietary supplements. Against this background, this chapter aims to contribute to the existing literature on consumer involvement in food and dietary supplements by exploring the following two research questions:

- To what extent are dietary supplements subject to a higher level of involvement than ‘ordinary food’ products?
- Which factors represent potential determinants of consumer involvement in dietary supplements?

5.2 Conceptual framework and development of hypotheses

5.2.1 Involvement definitions and scales

Extant literature delineates many definitions of the construct ‘involvement’ (Andrews et al., 1990; Aschemann-Witzel, 2009; Mittal & Lee, 1989; Peschel et al., 2016). Aschemann-Witzel et al. (2009) summarized involvement into the following four components:

- antecedents for the personal relevance (“needs, values, and interests”, Zaichkowsky, 1985),
- references to different objects (physical objective or situation, Costley, 1988),
- effects in different intensity and type (e.g. information behavior, Trommsdorff, 2011), and
- consistence of the construct involvement (“individual level, internal state variable”, Mitchell, 1979).

Mittal (1989a) defines involvement as the degree of interest and concern of a person in an object. The latter can be a product or purchase decision, whereby product involvement can (but not necessarily) be an antecedent to purchase-decision involvement (Mittal, 1989a; Peschel et al., 2016). This definition differs to the ‘food involvement’ by Bell & Marshall (2003) used in chapter 4, defined as “the level of importance of food in a person’s life” (p. 236). Whereas the definition by Mittal (1989a) refers to the decision process during the purchase situation, the definition by Bell & Marshall (2003) denotes a general interest in the specific topic of food. In order to measure and compare different level of involvement between two distinct product categories that are regulated as food in the EU, this chapter adopts the definition by Mittal (1989a).

Along with different definitions of involvement in purchasing situations, several scales have been developed to estimate this construct (e.g. personal involvement inventory: Zaichkowsky, 1985; foote, cone and belding grid model: Ratchford, 1987; consumer involvement profiles: Kapferer & Laurent, 1993; purchase decision involvement: Mittal, 1989a). The purchase decision involvement (PDI) scale developed by Mittal (1989a) was used because of its conciseness, convenience, validity and focus on involvement in the context of purchase. The

next section presents the development of the research model and the hypotheses of the consumer study.

5.2.2 Development of the research model and hypotheses

Ordinary food products provide the necessary nutrients for all basic bodily functions (utilitarian value) and generally require less cognitive effort. Their consumption provides sensory pleasure (hedonic value) and consumers' ethical concerns can also be represented (sign value) through specific food choice. In contrast, as mentioned earlier, dietary supplements may not provide sensory pleasure because of their format (e.g. pills, powder) and dosage. The ingredient is usually more important than the taste, texture and other sensory aspects in the case of dietary supplements. However, their consumption may have a positive impact on consumers' health (hedonic value). Since consumers seek dietary supplements for specific ingredients that provide additional health benefits that are not fulfilled by ordinary food products, their purchase may require more cognitive effort and can demonstrate nutrition knowledge and health awareness (sign value).

As mentioned in the introduction, ordinary food products are typically considered to be low-involvement products (Balderjahn & Scholderer, 2007; Beharrell & Denison, 1995; Jain & Srinivasan, 1990; Laurent & Kapferer, 1985). These products can be found rather commonly in the markets, the purchase decision is made rather habitual (Beharrell & Denison, 1995; Bell & Marshall, 2003; Wood & Neal, 2009), and thus, factors like quality and nutritional attributes may not necessarily be considered and understood in detail. As a result, the duration of the decision-making process tends to be short, the gathering of information is often rather passive and consumers only invest a limited degree of cognitive effort (Trommsdorff, 2011). In this case, the level of involvement in purchasing decisions could be low. Nonetheless, the involvement level in ordinary food products could be positively influenced by health related factors, which provide utilitarian values (e.g. consuming fiber-enriched cereals: Bolfing, 1988; fish: Verbeke et al., 2007; fruit and vegetables: Barker et al., 2008; Jarman et al., 2012; Lawrence et al., 2011; Marshall & Bell, 2004; Saba & Vassallo, 2012). With respect to dietary supplements, utilitarian attributes could be dominant and the level of involvement in purchasing decisions of these products could be higher. However, these relationships are also challenged by some studies (e.g. Sarmugam & Worsley, 2015). Therefore, to explore the first research question and assess the involvement level in purchasing decision of dietary supplements as compared to ordinary food products, the following hypothesis is derived:

H_1: Dietary supplements (DS) are subject to a higher level of purchase decision involvement than ordinary food (OF) products.

The second research question extends the analysis by exploring factors that represent potential determinants of consumer involvement in dietary supplements. Existing literature often refers more to consumers' product involvement than purchase-decision involvement. Nevertheless, involvement in a product category is closely associated with involvement in the decision of purchasing that product (Mittal & Lee, 1989). Generally, consumers tend to collect relevant information to reduce transactional risks and fulfil their own needs (Kim et al., 2010) when they purchase a certain product. Before taking purchasing decisions about dietary supplements, consumers may collect this information from a wide range of information sources such as journals, internet, and television. In the context of nutrition and health, it was found that respondents who were knowledgeable about food and nutrition were more likely to engage in healthy food behavior (Bogue et al., 2005; Mulders et al., 2018). This literature background motivates us to deduce the following hypothesis in the context consumers' purchasing decision of dietary supplements:

H_2: The more consumers use the provided information, the more they purchase dietary supplements.

With respect to consumers' involvement in a product category and their purchase behavior, Teng & Lu (2016) found that the degree of consumers' involvement in the purchase of organic food products was related to their actual intention to purchase the products (Teng & Lu, 2016). This means that the higher the level of consumer involvement in the purchasing process, the more likely they were to buy that product. Adapting this reasoning to dietary supplements could mean that if consumers are interested in dietary supplements, they would be more involved in the purchase decisions and eventually purchase these products. This relationship is explored by testing the following hypothesis:

H_3: The higher the consumers are involved with the purchasing decision, the more likely they are to actually purchase dietary supplements.

In general, consumers' decision making-process and information search seem to vary depending on their level of involvement (Park & Mittal, 1985). The more the consumers' felt involved in product advertisements, the more time (seconds) and attention they dedicated for processing each advertisement (Celsi & Olson, 1988). In the case of nutrition and health, consumers with higher involvement levels may process information differently and more intensively (e.g. be more receptive to health and food related messages) as compared to those

with low involvement levels who are unlikely to pay attention to any information about food and health (Sarmugam & Worsley, 2015). With regard to information search, Mittal (1989b) stated that information search is high only when the product is functional or utilitarian. When the product serves expressive (e.g. sign) goals, the consumer would not seek much information. Since dietary supplements are mainly characterized by their utilitarian 'health benefit', the following hypothesis in the context of involvement in dietary supplements was tested:

H_4: The higher the level of consumer involvement in the purchase of dietary supplements, the more intensive is the search for information about these products.

Existing research shows that health is a major motive that drives food consumption (Furst et al., 1996; Pieniak et al., 2008; Rankin et al., 2018; Sun, 2008; Van Loo et al., 2017). The construct 'health' can be measured through two main factors, namely health status and health motivation. Health status reflects the personal relevance toward a healthy diet (Kröber-Riel et al., 2009). Broadly, health status could be associated with a healthy diet, which requires being attentive to information related to food purchase and consumption. Attention, in turn, is associated with involvement. Therefore, consumers' health status can affect their use of the provided information and consequently their involvement in the product (Kröber-Riel et al., 2009). To assess the relationships between consumers' health status, use of information and involvement, the following hypotheses are formulated:

H_{5a}: The lower the health status of consumers, the higher is their use of the information provided.

H_{5b}: The lower the health status of consumers, the higher is their involvement in the purchase of dietary supplements.

Another important factor to explain the influence of involvement on purchasing decision of dietary supplements is health motivation. It refers to consumers' willingness to engage in preventive health behavior (Jayanti & Burns, 1998). Health motivated consumers are also known as health-conscious consumers. These consumers tend to be aware of and involved with nutrition. They also take proactive action by buying high quality and healthy food to enhance their wellbeing and improve or maintain their quality of life (Jayanti & Burns, 1998; Kraft & Goodell, 1993; Michaelidou & Hassan, 2010; Teng & Lu, 2016). In addition, the higher the consumers' health motivation, the more often he/she uses different information sources such as TV, internet websites and radio to gather information (Bornkessel et al., 2014). Since

involvement is associated with an active and intense information search, these findings indicate a positive relationship between health motivation and involvement. They also suggest a positive relationship between health motivation and search of information. Based on this literature background, the following hypotheses was developed:

H_{6a}: The higher the health motivation of consumers, the more often they use provided information.

H_{6b}: The higher the health motivation of consumers, the higher is their involvement in the purchase of dietary supplements.

Figure 5.1 illustrates the relationships and hypotheses that are deduced in the above section. Tables 5.1 and 5.2 summarize the construct definitions and hypotheses, respectively.

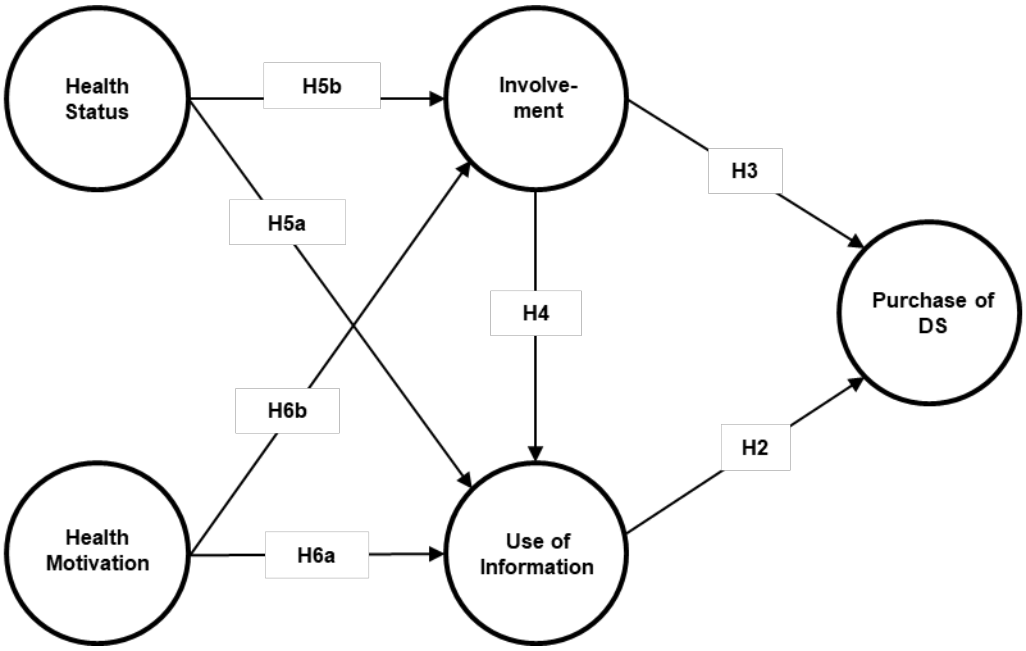

Figure 5.1: Research model for involvement model.

Source: Own illustration.

Table 5.1: Definitions of latent constructs within involvement model.

Variable	Construct	Operational Definition
HS	Health Status	Health status is the general condition of an individual by measuring health.
HM	Health Motivation	Health motivation refers to consumers' goal-directed arousal to engage in preventive health behaviors (Jayanti and Burns, 1998).
PDI	Purchase Decision Involvement	Purchase decision involvement is the extent of interest and concern that a consumer brings to bear on a purchase decision task (Mittal, 1989).
P-DS	Purchase of Dietary Supplements	Purchase of Dietary Supplements is the buying of dietary substances for the use by the respondent to supplement the diet by increasing of the total dietary intake.
UoI	Use of Information	The Use of Information describes the decision making process of an individual before purchasing goods under considering the given information of the several goods (Moorman, 1998).

Source: Own illustration.

Table 5.2: Hypotheses of involvement model.

Relationship		Hypotheses
PDI-DS vs PDI-NF	H_1	Dietary supplements (DS) are subject to a higher level of purchase decision involvement than ordinary food (OF) products.
UoI → P-DS	H_2	The more consumers use the provided information, the more they are purchasing dietary supplements.
PDI → P-DS	H_3	The higher the consumers are involved with the purchasing decision, the more likely they are to actually purchase dietary supplements.
PDI → UoI	H_4	The higher the level of consumer involvement in the purchase of dietary supplements, the more intensive is the search for information about these products.
HS → UoI	H_{5a}	The lower the health status of consumers, the higher is their use of the information provided.
HS → PDI	H_{5b}	The lower the health status of consumers, the higher is their involvement with the purchase of dietary supplements.
HM → UoI	H_{6a}	The higher the health motivation of consumers, the more often they use provided information.
HM → PDI	H_{6b}	The higher the health motivation of consumers, the higher is their involvement with the purchase of dietary supplements.

Source: Own illustration.

5.3 Materials and methods

5.3.1 Sample characteristics

A sample of 350 German consumers was interviewed via CATI (computer-aided telephone interview) in September and October 2012 to assess their involvement in both dietary supplements and ordinary food. The survey was carried out by a market research institute using the ADM (Arbeitskreis Deutscher Markt- und Sozialforschungsinstitute e.V.), a sampling-system which provides a representative random sample of Germany. Interviewees were chosen based on the criteria age (18 years and older) and general interest in dietary supplements. Dietary supplements were defined as 'all products which enable a specific intake/ absorption of vitamins, mineral and micro nutrients additional to the general food consumption as well as are sold in concentrated form, e.g. as vitamin pills, powder or liquid'.

5.3.2 Measurement of constructs

Table 5.3 summarizes all latent variables and manifest variables. The latent construct 'health status' (HS) was measured on a reflective scale with 4 items. The first item (general health status) is adapted from the Max Rubner-Institut (2008). The other three items, namely, health status in mobility, mental well-being and self-care, are based on the EQ-5D™ (EuroQol, 2013). Participants were asked to evaluate their health status on a 5-point Likert scale ranging from (1) 'very good' to (5) 'very poor'. The latent construct 'health motivation' (HM) was measured by a reflective scale based on Jayanti & Burns (1998) with aspects of health prevention and health concern. Consumers assessed their health motivation on a 5-point Likert scale reflecting the level of agreement to the statements. The latent variable 'Use of Information' (UoI) is adapted from Moorman (1998) and is measured by 4 items evaluated on a 7-Likert scale, which considers the source as well as the time spending on reading the information. The purchase-decision involvement (PDI) as perceived by consumers was measured on a 7-Likert scale with 4 items, based on Mittal (1989a). Finally, participants were asked about their frequency of purchasing dietary supplements (Purchase of dietary supplements, P-DS) on a scale of very often, often, from time to time, infrequent, never. The assessment was based on consumers' perception towards the purchase frequency.

Table 5.3: Constructs, items and statements for involvement model.

Latent variables	Manifest Variables		Scale	Source
Health Status	HS1	How would you general assess your health?	1=very good; 5= very bad	adapted from Max Rubner-Institut (2008)
	HS2	How would you assess your agility (physical), i.e. how good can you move around?		adapted from EuroQuol Group (2015)
	HS3	How do you assess your mental well-being?		
	HS4	How do you assess your capability to take care of yourself?		
Health motivation	HM1	I try to prevent common health problems before I feel any symptoms.	5-likert scale	
	HM2	I am concerned about common health hazards and try to take action to prevent them.		
	HM3*	I don't worry about common health hazards until they become a problem for me or someone close to me. *[*reversed coding]*		
	HM4*	Because there are so many illnesses that can hurt me these days, I am not going to worry about them. (Because it is so vast for me I do not worry.) *[*reversed coding]*		adapted from Jayanti and Burns (1998)
	HM5*	I don't take any action against common health hazards I hear about until I know I have a problem. *[*reversed coding]*		
	HM6*	I would rather enjoy life than try to make sure I am not exposing myself to a health hazard. *[*reversed coding]*		
Use of Info.	UoI1	I usually pay attention to dietary supplements when I get information about them in an advertisement or elsewhere.	7-likert scale	
	UoI2	I use the information on the packaging when making my dietary supplement selection.		Moormann 1998
	UoI3	I spend much time in the supermarket reading nutrition information on the packaging of dietary supplements.		
	UoI4	I read about nutrition in magazines, books as well as in the internet.		
Purchase Inv. of DS	PDI1	In selecting from the many types and brands of dietary supplements available in the market, I would care a great deal as to which product/ (pharmaceutical) preparation I buy.	7-likert scale	
	PDI2	The various types and brands of dietary supplements available in the market are all very different.		Mittal (1989)
	PDI3	For me it is extremely important, that I make the right choice of a dietary supplement preparation.		
	PDI4	In making my selection of the dietary supplement, I am very much concerned about the outcome of my choice (“did I buy the right product”?).		
Purchase of DS	P-DS	I buy dietary supplements…	1= very often; 5= never	--

Remark: DS=Dietary supplements; Info.=Information; Inv.=Involvement.

Source: Own illustration.

With respect to socio-demographics, consumers were asked to respond about their gender and age (in years). Their education was measured on three levels: practical education, academic education and none of them. For the monthly household net income, consumers could choose between less than 500€, 501-1500€, 1501-4500€, more than 4500€ and no response.

5.3.3 Data analysis

Non-parametric tests as the Kolmogorov-Smirnov Test of normality indicated that not all variables were normally distributed. The Wilcoxon signed-rank test (using SPSS 24) was used to analyze the difference between involvement in dietary supplements and ordinary food products in total and also individually. It investigated whether the mean ranks from the same participants differ (Field, 2009) (e.g. a participant scored 20 for the involvement in dietary supplements and 17 with ordinary food products).

To test the overall research model, variance-based partial least squares structural equation modeling (PLS-SEM) was conducted by using SmartPLS 3 (see also section 4.3.3). PLS-SEM was designed for analysis of high dimensional data in a low-structure environment (Henseler et al., 2009) and was applied and extended in various papers (Bruwer et al., 2017; Hartmann et al., 2016; Ting et al., 2016; Wu et al., 2016). The PLS path model consists of two sets of linear equations: the inner model (i.e. the relationships between unobserved/latent constructs), and the outer model (i.e. the relationships between a latent construct and observed/manifest variables). In the inner model, the model within this study analyzed the relationship between the exogenous (independent) variables HS and HM and the endogenous (dependent) variables PDI, UoI as well as P-DS. The outer model is determined by reflective measured variables.

5.4 Results

5.4.1 Study sample

In the beginning of the interview, consumers were asked about their general interest in dietary supplements (How high is your interest on dietary supplements? Answer options: 1=very high, 5=very poor), whereby an answer of at least ‘3=partly’ was necessary to continue the interview. Initially, 1,316 consumers were willing to participate in the study. In the end, 350 interviewees stated to have ‘very high’, ‘high’, ‘partly’ interest on dietary supplements and thus,

constitute the final study sample (Table 5.4). 778 and 188 consumers indicated ‘very low’ and ‘low’ interest, respectively, and the interview ended after the screening criteria. This was based on the experience from the pre-test that consumers with low interest dropped out of the study during the telephone interview. This resulted in 26.6% consumers who were interested in dietary supplements and participated in the final study. Therefore, it is assumed that the sample consists of participants who are willing to purchase dietary supplements and represent consumers of these products in Germany.

Respondents’ age ranged from 18 to 83; nearly 2/3 of the respondents were female and about 57% stated to have practical education as their highest education. The half of the respondents had a monthly income of 1,501 to 4,500€, and nearly 20% were not willing to state their income. Most consumers indicated to buy dietary supplements ‘sometimes’, followed by ‘often’ and only some stated to purchase them ‘very often’. 3.7% of respondents answered that they never buy dietary supplements.

Table 5.4: Descriptive statistics of manifest variables for dietary supplement sample.

Age			
Min/Max	Median	Standard deviation	Variance
18/83	43	13,478	181,651

		N (total 350)	**%**
Gender	female	221	63.1
	male	129	36.9
Education (highest)	practical education	199	56.9
	academic education	120	34.3
	none of them	31	8.9
Income (monthly household income)	less than 500€	4	1.1
	501 – 1500€	72	20.6
	1501 – 4500€	175	50.0
	more than 4500€	30	8.6
	no statement	69	19.7
General interest in dietary supplements	very high	44	12.6
	high	130	37.1
	partly	176	50.3
Purchase of dietary supplements	very often	27	7.7
	often	120	34.3
	sometimes	145	41.4
	infrequent	45	12.9
	never	13	3.7

Source: Own illustration.

5.4.2 Direct comparison of involvement in dietary supplements compared to ordinary food products

To decide where cut off points for low and high involvement were on the scale, involvement distributions of dietary supplements and ordinary food products were tabulated (see Figure 5.2). The sample mean of the category dietary supplements is 21.17, and for the category of ordinary food products 20.65, whereas the true theoretical mean is 16. This deviation from the theoretical mean could be because of the product-dependent nature of the distribution.

The distribution derived from the data was classified into low, medium, or high involvement. Following Zaichkowsky (1985), low scorers were defined as those scoring in the first quartile of the distribution-ranging from 4 to 18. Medium scorers were defined as those scoring in the middle 50% of the distribution-ranging from 19 to 23. High scorers were defined as those scoring in the top quartile of the distribution-ranging from 24 to 28. Results of the Wilcoxon signed-rank test for the difference between involvement scores of dietary supplements and ordinary food products are presented in Table 5.5. The involvement scores were significantly higher for dietary supplements than ordinary food products (p= .01). In specific, 168 participants' involvement scores for dietary supplements were higher than ordinary food products and only 128 times in the opposite direction. Participants' involvement in ordinary food products and dietary supplements does seem to differ, since they had the same involvement score for both product groups only 54 times.

Table 5.5: Wilcoxon signed-rank test for differences between involvement scores of dietary supplements and ordinary food products.

Ranks for PDI-DS – PDI-OF				**Statistic for Test[a]**	
	N	**Mean Rank**	**Sum of Ranks**		**PDI-DS–PDI-OF**
Negative Ranks	168[a]	153.33	25759.00	Z	-2.579[b]
Positive Ranks	128[b]	142.16	18167.00	Asympt. Sig. (2-tailed)	0.010
Ties	54[c]			a. Wilcoxon Signed Ranks Test	
Total	350			b. Based on positive ranks.	
a. PDI-OF-total < PDI-DS-total					
b. PDI-OF-total > PDI-DS-total					
c. PDI-OF-total = PDI-DS-total					

Remark: DS=Dietary supplements; OF=Ordinary food products; PDI=Purchase decision involvement.

Source: Output of SPSS.

The differences between the mean and median of participants' involvement scores (Figure 5.2) as well as the result of their involvement scores for dietary supplements being higher than

for ordinary food products (as seem from the Wilcoxon signed-rank test) suggest that H_1 cannot be rejected. Therefore, it could be said that dietary supplements are subject to consumers' higher level of purchase decision involvement as compared to ordinary food products.

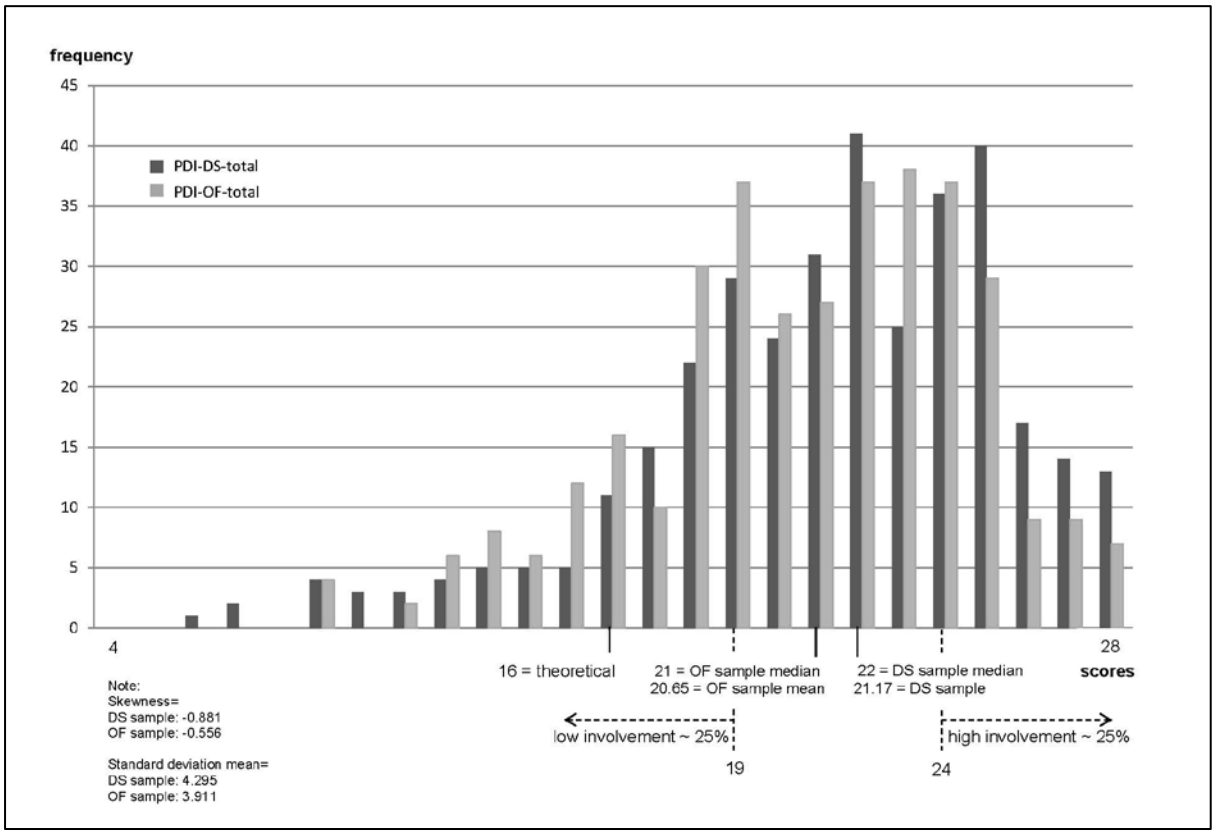

Figure 5.2: Distribution and classes of involvement scores for dietary supplement sample.

Remark: OF = ordinary food, DS = dietary supplements.

5.4.3 Evaluation of reflective measurement model

Reflective measure constructs are determined for the outer model. These items are highly correlated and interchangeable for their relevant latent construct (Hair et al., 2013). The PLS-SEM algorithm could find a stable solution within eight iterations. Results are depicted in Table 5.6. For the explanation and tresholds of the different reflective measurement model evaluation criteria, please refer to section 4.4.3 (and also Hair et al., 2014).

Table 5.6: Results summary of reflective measurement model for involvement model.

Variables	Indicators	Loadings[a]	Cronbach's alpha[b]	Composite reliability[b]	AVE[c]
Health Status	HS1	0.212	0.742	0.017	0.158
	HS2	0.272			
	HS3	0.370			
	HS4	-0.615			
Health Motivation	HM1	0.832	0.766	0.674	0.312
	HM2	0.884			
	HM3[r]	0.408			
	HM4[r]	0.147			
	HM5[r]	0.290			
	HM6[r]	0.359			
Use of Information	UoI1	0.734	0.729	0.830	0.609
	UoI2	0.642			
	UoI3	0.769			
	UoI4	0.813			
Purchase Decision Involvement	PDI1	0.813	0.783	0.861	0.609
	PDI2	0.677			
	PDI3	0.820			
	PDI4	0.802			
Purchase of Dietary Supplements	P_DS	1.000	1.000	1.000	1.000

Remark: [a] Treshold ≥ 0.708; [b] Treshold ≥ 0.7; [c] AVE=Average variance extracted, treshold ≥ 0.5 (Hair et al., 2013); [r] Reversed coding.

Source: Own illustration based on outputs of SmartPLS 3.

Convergent Validity – First, the convergent validity was tested with two measurements, i.e. the outer loadings of the indicators and the average variance extracted. Although results presented in Table 5.6 showed issues related to convergent validity, the AVE values met the necessary threshold of 0.5, and after deleting HS4, HM4[r], HM5[r] and HM6[r] almost all outer loadings are above the threshold of 0.708 (Hair et al., 2013).

Internal consistency reliability – Cronbach's alpha and composite reliability are used for testing internal consistency reliability (see Table 5.6). HS and HM have composite reliable issues but reach the thresholds of 0.7 (Hair et al., 2013) after deleting the four items mentioned in the section of 'convergent validity', and result in internal consistent reliable items.

Discriminant validity – The discriminant validity of the latent constructs was evaluated by the Fornell-Larcker Criterion and the Heterotrait-Monotrait Ratio (HTMT). All tresholds could be met, thus, all constructs are discriminant valid (see Table 5.7).

Table 5.7: Discriminant validity criteria for involvement model.

	HM	HS	PDI	P-DS	UoI
HM	0.748				
HS	0.023 *(0.160)*	0.771			
PDI	0.335 *(0.402)*	0.041 *(0.072)*	0.780		
P-DS	0.394 *(0.471)*	0.052 *(0.063)*	0.423 *(0.475)*	1.000	
UoI	0.406 *(0.473)*	0.038 *(0.110)*	0.540 *(0.704)*	0.418 *(0.468)*	0.742

Remark: Treshold for Fornell-Larcker Criterium (standard) to indicate discriminant validity: √AVE > correlation with other constructs; Heterotrait-Monotrait Ratio (HTMT) *(italic)* ≥ 0.85.

Source: Own illustration based on outputs of SmartPLS 3.

5.4.4 Assessment of overall structural model

After evaluating the construct measures for their reliability and validity, the structural model was assessed by the PLS method (Figure 5.3). If path coefficients were significant, bootstrapping with 5,000 subsamples and a significance level of 0.05 on the basis of a two tailed test was performed. For the explanation and tresholds of the different criteria to assess the structural model results, please refer to section 4.4.4 (and also Hair et al., 2014).

Multicollinearity assessment – Multicollinearity assessment showed VIF values to be below 5 (ranging from 1.001 (HM→PDI) and 1.411 (PDI→P-DS)), indicating no collinearity problem in the structural model between the latent constructs.

Coefficient of variance (R^2) – In this study, R^2 value of the endogenous variables PDI (0.113), UoI (0.349) and P-DS (0.230) indicate that the model has weak explanatory power.

f^2 Effect Size – All predictors have small and medium explanation to the R^2 value of the endogenous variables, i.e. HS (0.001 and 0.000) has no effect on PDI and UoI. HM (0.126 and 0.088) has a small effect on PDI and UoI. Further, PDI (0.281 and 0.071) has also a medium effect on UoI and small effect on P-DS. UoI (0.066) has a small effect on P-DS.

Cross-validated redundancy (Q^2) – The blindfolding procedure resulted in Q^2 values greater than 0 for all endogenous constructs-PDI (0.060), UoI (0.173) and P-DS (0.216) indicating the model's predictive relevance for these constructs.

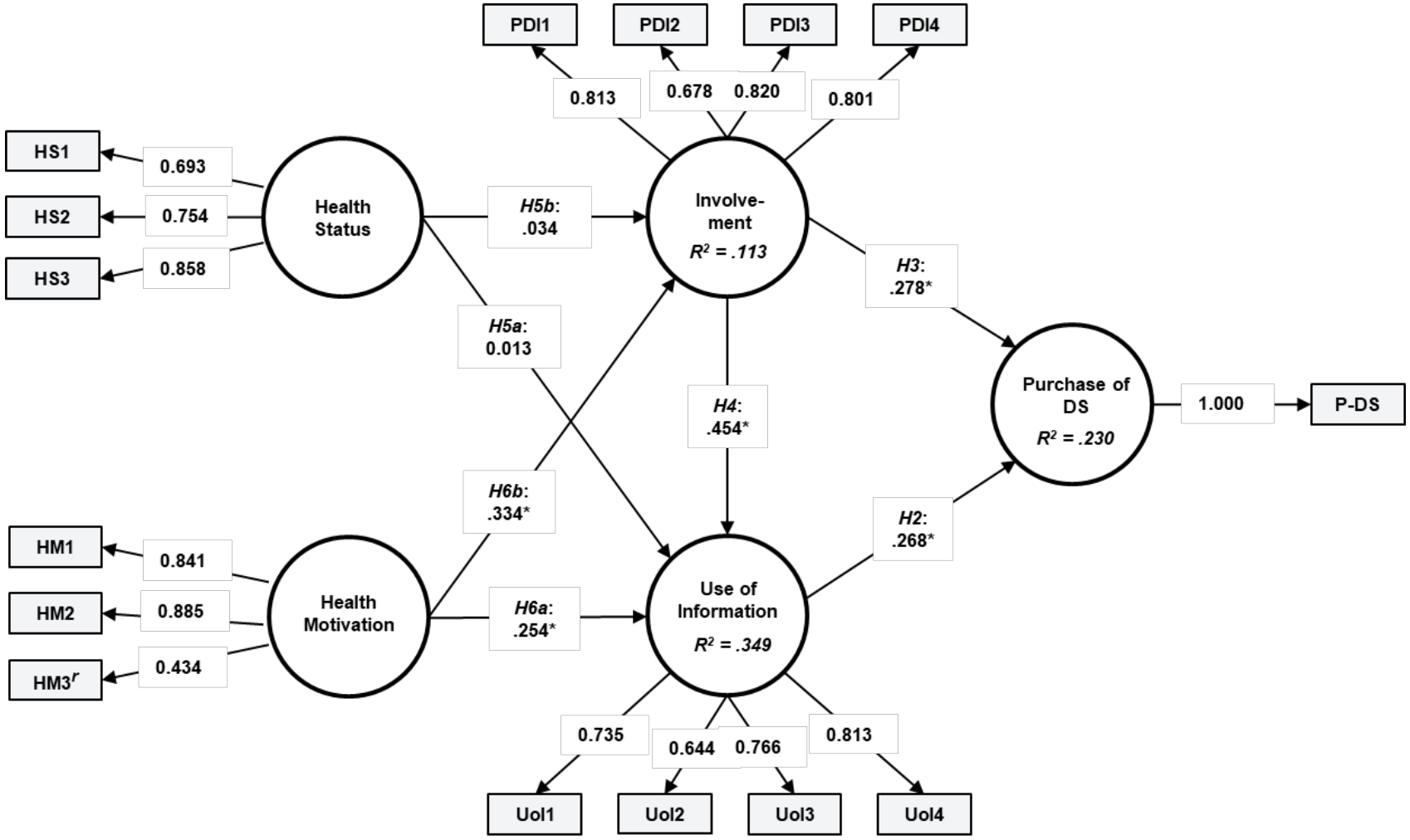

Figure 5.3: PLS path coefficients and bootstrap statistics for involvement model.

Remark: * = *p*-value (0.000), ʳ reversed; R^2-values ≥ 0.75, 0.5, 0.25 indicate substantial, moderate and weak explanatory power; PLS-SEM with maximum 5,000 iterations and stop criterion at 10^{-7}.

Source: Own illustration based on SmartPLS 3 output.

The path coefficients and hypotheses testing – Since the path coefficients of relationship between HS and UoI as well as PDI were found to be nonsignificant (Figure 5.3), H_{5a} and H_{5b} have to be rejected. No significant influence of health status on consumers' use of information about and involvement in the purchase of dietary supplements was found. Furthermore, results indicate a reverse relationship than the hypothesized one, i.e. the higher the consumers' health status, the higher is their involvement in the purchase of DS. The hypotheses H_{6a} and H_{6b} cannot be rejected at a 1%-significance level. This signifies that the higher the health motivation of consumers, the more often they use the provided information (0.254, *p*= .000), and the higher is their involvement in the purchase of dietary supplements (0.334, *p*= .000). Further it can be said, that the higher the consumers are involved with the purchase of dietary supplements, the more intensive is their search for information. This hypothesis (H_4) shows a strong relationship between both constructs (0.454, *p*= .000). Finally, it cannot be rejected that if consumers are highly involved with purchase of dietary supplements or use provided information, they may purchase more dietary supplements (H_3: 0.278, *p*= .000; H_2: 0.268, *p*= .000).

5.4.5 Socio-economic influences

Socio-economic characteristics of individuals such as age, gender, education and income in the context involvement in dietary supplements are analyzed by using the non-parametric Kruskal-Wallis-Test (Table 5.8). Results show that older participants were higher involved than younger participants (*p*= .024). The difference between the mean ranks of consumers' purchase decision involvement in dietary supplements regarding gender is supported at the 1%-significance level. Compared to male, female consumers scored higher on their involvement decision behavior. The Kruskal-Wallis Test indicates that the mean ranks of involvement do not differ significantly between consumers based on the level of education (*p*= .814), but do vary between income groups (*p*= .007). Individuals who are earning less than 500€ per month have the highest mean rank (219.63). The groups '1501-4500', 'more than 4500' and 'no statement' have almost the same mean rank and do differ significantly to the mean rank of the income group '501-1500€'. Thus, it can be stated that higher income groups show a higher involvement in the purchase of dietary supplements.

Table 5.8: Results of Kruskal-Wallis test for grouping Purchase Decision Involvement.

		Ranks		**Test Statistics for Grouping variable and PDI**		
Grouping variable	Group definitions	N	Mean Rank	Chi-Quadrat	df	Asymp Sig.
Age [in years]	18-39	146	163.91	7.428	2	0.024
	40-61	163	176.61			
	62-83	41	212.37			
Gender	male	129	157.24	6.702	1	0.010
	female	221	186.16			
Highest education	practical education	199	173.69	0.411	2	0.814
	academic education	120	175.75			
	none of them	31	186.16			
Income (monthly)	less than 500€	4	219.63	14.072	4	0.007
	501 – 1500€	72	136.76			
	1501 – 4500€	175	182.92			
	more than 4500€	30	186.92			
	no statement	69	189.58			

Remark: PDI=Purchase decision involvement.

Source: Own illustration based on outputs of SPSS.

5.5 Discussion

In this chapter, involvement of consumers in dietary supplements was analyzed and important influencing determinants of their purchasing decisions were identified. With respect to the first research objective, results indicate that in comparison to ordinary food products, consumers seem to be more involved in purchase decisions of dietary supplements. This could imply that in contrast to food products, consumers purchase supplements with a greater level of cognitive effort, i.e. with an intensive search for and use of existing information. The higher involvement in the purchase of dietary supplements as compared to ordinary food products might be due to the different decision patterns based on the utilitarian, sign and hedonic values associated by consumers to the products. The ‘core competence’ (Prahalad & Hamel, 1990) of dietary supplements, i.e. the utilitarian-value ‘health benefit’, is directly identifiable, whereas for ordinary food products the core benefit is encapsulated by several layers (i.e. sign-value ‘social impression management goals’ or hedonic-value ‘sensory pleasure’). Results of this study, which suggest that consumers are higher involved in the purchase of dietary supplements than in ordinary food products can also be supported by Bolfing (1988), Verbeke et al. (2007) or Barker et al. (2008) who assert that health related food, such as fiber-enriched cereals, fish or fruit and vegetables, respectively, seem to influence the involvement level positively.

With regards to the second research objective, health motivation – especially in the form of a high prevention tendency – is an important predictor for purchase decision involvement and use of information. These factors, in turn, affect actual purchase behavior of dietary supplements. Health status has no significant influence on purchase decision involvement or actual purchase of dietary supplements. One explanation for this may be that people with lower health status eat less healthy (Eertmans et al., 2005) and pay less attention to their dietary consumption behavior as compared to those who take dietary supplements regularly and have healthy dietary consumption behavior. Broadly, the consumer segment (e.g. with deficiencies) to whom dietary supplements are targeted appears to purchase fewer of these products as compared to healthy consumers who probably have higher health motivation. This may indicate a mismatch between the intended target group and product offerings (Max Rubner-Institut, 2008). In line with other results, consumers motivated about health are involved higher in the purchase decision and will pay more attention to the information (e.g. packaging) (Nørgaard & Brunsø, 2009; Vila-López & Kuster-Boluda, 2016). Further, consumers with higher levels of purchase decision involvement may not practice healthier dietary habits by buying dietary supplements exclusively, but in general demonstrate healthier and well-balanced dietary behavior (e.g. higher consumption of fruit and vegetables) (Barker et al., 2008; Jarman et al., 2012; Lawrence et al., 2011; Marshall & Bell, 2004; Sarmugam & Worsley, 2015).

Regarding socio-economic factors, age (+), gender (female) and income (+) have a positive influence on consumers' purchase decision involvement in dietary supplements. However, the level of education has no significant impact on their level of involvement. Literature explains that older individuals were found to have higher food involvement scores as they are likely to have more experience with the food lifecycle (Bell & Marshall, 2003; Puhakka et al., 2018). In the context of fresh meat, younger consumers are rather lowly involved (Verbeke & Vackier, 2004). It was also found that older people are more likely to be highly involved with grocery products due to physiological changes that motivate them to invest more in their health (Drichoutis et al., 2007). Another study of 894 lab employees, graduate students enrolled in a public health program, and undergraduates in a military academy found that women were higher involved with food than men, which may be explained by their role in the society (Bell & Marshall, 2003; Hansen et al., 2010; Kähkönen & Tuorila, 1999; Vila-López & Kuster-Boluda, 2016). With respect to education, higher education results in higher food involvement as highly educated consumers may enjoy eating and place higher priority on cooking in their lives (Barker et al., 2008; Jarman et al., 2012; Sarmugam & Worsley, 2015). However, Verbeke & Vackier (2004) did not find a significant impact of the individuals' educational background on involvement in fresh meat. In the context of grocery products, the involvement

scale was negatively correlated with education. This could be explained by the limited time dedicated by educated people to purchasing grocery (Drichoutis et al., 2007). Echoing the empirical findings from existing literature, it could be determined that involvement has an impact on the purchasing frequency, which in turn is influenced by a variety of different determinants (Barker et al., 2008; Drichoutis et al., 2007; Trommsdorff, 2011; Van Trijp & Van der Lans, 2007).

It is also important to understand consumers' involvement with respect to the purchase decision of ordinary food products. Depending on the context, ordinary food does not always need to be a low involvement product. Analyzing consumer involvement in ordinary food products provides many useful consumer behavior explanations. The results of this chapter are of managerial relevance in the context of health claims administered under the so-called Nutrition and Health Claims Regulation (EC) No. 1924/2006. Information for either a nutrition or function claim or a claim about the reduction of disease risk is communicated by product advertisement and packaging, and needs to be understood by the average consumer. Different consumer involvement levels indicate a need for targeted advertisement and communication strategies as low, middle and high involved consumers with their buying choices may process information differently (Chrysochou et al., 2010; Mittal, 1989a; Petty & Cacioppo, 1981; Sarmugam & Worsley, 2015). Consumers with higher levels of involvement are more likely to be receptive to health and food related messages. Communication strategies with complex information (e.g. communicated by health professionals) may appeal to these highly involved consumers (Sarmugam & Worsley, 2015). Conversely, consumers who have low involvement in the purchase of dietary supplements are unlikely to pay attention to information about food and health. These target groups can be reached by using communication strategies which can be processed via peripheral routes of persuasion, for instance via manipulation of environmental cues (Honkanen & Frewer, 2009). For an actual purchase of dietary supplements, consumers need to be aware about these products. The chain of effects for higher knowledge starts with health motivated consumers who will likely be higher involved with healthy food choices (Vila-López & Kuster-Boluda, 2016) and seek information (Hansen et al., 2010), which results in higher knowledge about dietary supplements. The results of this chapter suggests, that health motivation influences involvement in dietary supplements. Companies can valorize their product development efforts by encouraging consumers to be health conscious and being a catalyst in increasing their involvement in dietary supplements. Dietary supplements can contribute to a sufficient nutrition supply, but its correct consumption (right product in the right quantity) needs to be ensured to avoid overconsumption. Consumer understanding of the primary function and possible health hazards of dietary supplements requires dissemination of relevant knowledge

which should be provided by organizing health information campaigns. Overall, policymakers can benefit from this research in the broader context of consumer protection with respect to nutrition and health.

5.6 Conclusion

This chapter provides interesting insights about consumer involvement in dietary supplements. To this end, it also attempts to contribute to the existing literature on functional food and health claims (e.g. Aschemann-Witzel, 2009; Bornkessel et al., 2014; Nocella & Kennedy, 2012). This chapter aims to offer a better understanding of the factors promoting the purchase of dietary supplements and also the time dedicated by consumers to read and understand the packaging information, which itself is related to the degree of involvement. Moreover, by presenting a means to segment the German population in relation to their level of purchase involvement, it provides useful insights for marketing professionals and policymakers. In this context, results indicate that there is a need to develop customized approaches for communicating and promoting healthy eating habits in general.

Nevertheless, the study in this chapter suffers from some limitations which open avenues for future research. First, due to restricted resources only German consumers are included in the sample. Consumer behavior across different countries may vary in the context of purchasing dietary supplements and future studies may focus on a cross-country comparison of the topic at hand. Although the sample was collected in year 2012, it confirms results from existing literature and is relevant in the context of current consumer research on dietary supplements (e.g. Khedkar et al., 2017). Thus, it still offers valid implications for policymakers and processing food industry. Furthermore, the generality of Mittal's 'mind-set approach' to involvement limits detailed situational analysis. In this regard, the PDI-scale limits the research to study consumers' perception of purchase involvement rather than their actual involvement and purchase behavior. The latter is also limited by the perceptional assessment of consumers in terms of their frequency of purchasing dietary supplements rather the actual frequency. Furthermore, the small difference between the involvement in dietary supplements and ordinary food products can be assumed to be due to general high interest of consumers to purchase healthy food and obtain appropriate nutrition intake, expected to be impacted by the applied quota of 'general interest in dietary supplements'. Nevertheless, the drop-out rate of 73% initial respondents caused by low interest on dietary supplements indicates that the target group for purchasing dietary supplements is rather small. In order to assess the involvement of dietary supplements, the respective target group had to identified, and thus, the quota was

assessed. However, more than half of the included respondents indicated a partly interest in dietary supplements, indicating that interest in supplements was still diverse and limited.

Future research could study the impact of consumers' nutritional knowledge and awareness on purchase of dietary supplements as knowledge is a significant factor for consumer acceptance (Lusk et al., 2014; Ronteltap et al., 2007). Other important factors that can be analyzed in the context of health are self-efficacy (the belief that target behaviors which mitigate health threats can be successfully implemented) and response efficacy (the extent to which a person believes a particular health care action mitigates a health threat) (Jayanti & Burns, 1998; Tudoran et al., 2012). Overall, a comprehensive understanding of consumer involvement in the domain of food and dietary supplements could contribute toward identifying consumer-led solutions to the many challenges faced by companies and policymakers in the EU in the broader context of food.

The many challenges in the food system as presented in chapter 1 require efforts of consumers to eat more healthy (chapter 5) and to adapt to the outcomes of a continuous changing food system by adopting new foods produced by new food technologies (chapter 4). It also needs active participations of all chain actors in the food supply chain. Thus, the next two chapters investigate traders as representative of the supply side of the food chain. Therefore, the cost-effectiveness of the introduced new food technology, i.e. improved tomato packaging, is assessed (chapter 6) in order to enable the analysis of traders' evaluation toward these technology (chapter 6 and 7). Hence, in line with the focus of this thesis, different factors influencing traders' evaluation of improved packaging are examined.

Part IV: Empirical trader studies

6 Traders' evaluation on use of linings for improving tomato packaging in wooden crates and its cost-effectiveness

Chapter 6 answers Research Question 5 and its respective sub-questions:

RQ 5: What determines traders' evaluation toward new food technologies exemplified on an improved tomato packaging?

RQ 5.1: What is the effectiveness of introducing different lining material to enhance tomato packaging?

RQ 5.2: To what extent perceive traders the net benefit of improved tomato packaging as determinant for willingness to adopt the improved tomato packaging?

This chapter is based on the following publication:

Kamrath, C., Rajendran, S., Nenguwo, N. and Afari-Sefa, V. (2016): Traders' perceptions and acceptability on use of linings for improving tomato packaging in wooden crates. *International Journal of Vegetable Science 22 (6):* 530–540. DOI: 10.1080/19315260.2015.1076920.

6.1 Introduction

This chapter provides insights into the evaluation of new food technology evaluation from the supply side of the food chain. The supply side is exemplary represented by traders in Tanzania in the context of evaluating improved tomato packaging.

Tomato (*Solanum lycopersicum* L) has a good market demand and is rich in several micronutrients (Keatinge et al., 2009; Ojiewo et al., 2010; Palada et al., 2005; Weinberger & Msuya, 2004; Weinberger & Swai, 2006). In Tanzania, tomato postharvest losses are extremely high due to perishability, lack of awareness and knowledge of postharvest handling techniques, and poor packaging (Kereth et al., 2013). Reduction of postharvest losses of vegetables can contribute substantially to addressing food availability gaps (Afari-Sefa et al., 2012; Affognon et al., 2015) without use of additional production resources while enhancing livelihood of smallholder producers, a significant portion of the agricultural sector (Kaminski & Christiaensen, 2014). Smallholder producers in Tanzania usually operate on <2 ha of land and mostly grow vegetables (Weinberger & Msuya, 2004), of which tomato is considered one of the most commercially transporting tomatoes in Tanzania. Physical bruising of tomatoes during transport from rural collection centers to wholesale and retail markets is a typical occurrence. Fruits, which vary in shape, are mostly tightly packed in wooden crates weighing approximately 40 kg each, allowing for produce bruising during handling and transport. The wooden crates are often constructed from soft and poor quality timber, resulting in losses between 30% and 40% per crate (Kereth et al., 2013) due to their rough edges and rubbed surfaces. Reducing high tomato losses during transportation decreases overall food losses, which tends to improve the economic value of crops. Kitinoja et al. (2011) reported that corrugated fiber box liners on four sides and the base in plastic crates was more profitable. Perforated paper, or Hessian cloth lining, can be used to protect tomato fruit transported in standard wooden crates, but additional cost needs to be factored in by users. Smaller packing containers, with paper liners for existing containers, may reduce losses, are cost-effective, easy to use and have the capability to generate increased income (Kitinoja, 2013). The latter is especially an important adoption factor (Benzing & Chu, 2009; Feder et al., 1985).

Although several alternative packaging materials are available, high postharvest losses are often incurred through use of wooden crates. The observed produce losses incurred have not been addressed in the tomato supply chain in Tanzania. Therefore, the research questions of this chapter are:

- What is the effectiveness of introducing different lining material to enhance tomato packaging?

- To what extent perceive traders the net benefit of improved tomato packaging as determinant for willingness to adopt the improved tomato packaging?

6.2 Materials and methods

This chapter examined the acceptability of lining enhanced material for tomato packaging in wooden crates via on-station simulation trials (field experiments). Lining material with good potential to reduce damage to tomato fruit was added to standard wooden crates and evaluated and compared to wooden packing crates that did not have lining material. This was followed by identification of tomato traders supplying tomatoes to the main market in Arusha region who were surveyed to determine their responses to use of packing materials. A standard financial cost-benefit analysis approach was used to compare the treatments for their profitability.

6.2.1 On-station trial to test effectiveness of lining material

The on-station trial was conducted at AVRDC-The World Vegetable Center's Regional hub for eastern and southern Africa located in Arusha, Tanzania. Three packaging materials were compared, i.e. standard wooden crates (commonly used method), wooden crates lined with paper, and wooden crates lined with the Hessian cloth, a loose woven fabric made from jute. The tomato cv. Tanya was selected due to its popularity with farmers and its desirable postharvest traits (fruit qualities), firmness, good taste, long shelf-life, and ability of the fruit to endure rough handling during postharvest transport with minimal damage (Shenge et al., 2010). Thirty crates of 'Tanya' tomatoes were purchased from Kilombero wholesale market of Arusha region in Tanzania and re-sorted to remove poor quality and damaged fruit, resulting in 23 crates of uniform quality tomatoes. Fruit were then packed in seven crates of each packaging treatment, stacked in a 2-ton truck, and transported 40 km on an identified bumpy road within Arusha region (of a similar distance and road condition for tomatoes transported from the farm gate to the wholesale market in Arusha, as suggested by representatives of tomato truck drivers and tomato wholesalers, both of whom had considerable experience in the tomato transporting business in the Arusha region). The level of damage was evaluated one day after transport. Tomato fruit were categorized as marketable and cull. Good marketable fruit had no or minor damage and bruises. Culls were sorted into internally bruised fruit, mainly caused by being squeezing or compression by surrounding tomatoes, identified by water-soaked areas and wrinkled skin, and externally bruised fruit, which were those with

notable open cuts and broken skin caused by abrasions, mainly caused by rough surfaces on the wooden crates. These (culls) are barely or poorly marketable.

6.2.2 Study region

The Arusha region was chosen for this study because it is one of the major tomato producing regions of Tanzania. The Kilombero market was used for the traders' survey because it is one of the largest wholesale markets for tomatoes in the Arusha region as per expert opinion from various value chain actors, including the chairman of the Kilombero Market Association. The market is regulated by the Tanzanian Traders Association, which determines who has access to the market for trading purposes, offering an opportunity to identify an ideal sample from the population for purposes of this study. Tomato production in Tanzania usually spans two seasons annually: the main production season is usually from July to November (high season, low prices) and the minor season from February/March through to May/June (low season, high prices). Actors involved in the tomato supply chain with respect to trading practices include village collectors/commission agents, wholesalers, retailers, transporters, and porters, among others.

6.2.3 Survey design and evaluation studies

Two field traders' surveys were conducted in the study region: the first was a field-level survey conducted at retail markets to obtain data on tomato retailing parameters in the Arusha region, and the second involved a subjective assessment of trader perceptions on alternative tomato packing material using lining in wooden crates at wholesale market.

The first survey was designed to obtain detailed information on tomato trading as well as assessing physical losses at the retail level. The survey was carried out with four purposively selected retailers from the Kilombero wholesale market. Respondents included three women aged 37, 40, and 50 years, with 7, 3, and 20 years of experience in tomato trading, respectively, and one male aged 50 years with 13 years of experience in tomato retailing. For each retailer, one tomato crate was offered (price ranged from TZS 24,000 to 25,000 [US$14.50–US$15.10]). The Tanzanian shilling (TZS) is the local currency, with an exchange rate of TZS 1,655 to US$1 at the time of the survey for which respondent information on income accrued was collected.

In the second field trader survey in June 2014, 80 traders were interviewed in the Kilombero wholesale market, Arusha, to understand behavioral patterns toward adoption of alternative packaging material for tomato. Respondents included different trader categories: retailers (*N*=19), village collectors (*N*=13), and wholesalers (*N*=48). All trader categories were treated separately in the analysis. Initially, the aim was to utilize a stratified sampling procedure. However, this was not possible because the sampled population of wholesalers, village collectors and retailers was unknown in the study region. More precisely, it is typical for actual number of traders to change on a daily basis because several nonregistered members of the traders' association are allowed to sell produce at the market. Consequently, a stratified random sampling procedure was applied, i.e. nearly all wholesalers and village collectors who were present at the Kilombero wholesale market at the time of sample collection were interviewed. It is important to note that the Kilombero wholesale market is one of the biggest tomato wholesale markets in the Arusha region of Tanzania. Indeed, the only wholesale market for tomatoes in Arusha exists at the Kilombero market, which is why it was selected as the context of this study. Of the wholesalers interviewed, 41 were members of the local traders' association and 7 were nonregistered members. The exact number of village collectors is unknown. However, 13 village collectors were interviewed over a period of 4 days. As a further step, it was also gathered approximate census figures from the market manager in order to determine both the number of tomato retailers that operate in the Kilombero wholesale market (approximately 160 retailers), and how many retailers located outside the market tend to source and buy their produce from there. From the resulting list that was generated, 19 retailers were then randomly selected.

A structured survey questionnaire was used to test the theoretical model of this study. Three enumerators were trained on how the survey had to be conducted. As part of their training, enumerators were made to become conversant with the knowledge about the improved packaging and how to introduce the concept to traders and place it in context for the interview (see Appendix H for full questionnaire). An example of the lining material proposed was shown to traders. Following a pre-test of the survey instrument, face-to-face interviews on the paper based questionnaire were translated from English to Swahili, and were then conducted directly in the market.

Wholesalers, village collectors, and retailers responded to questions on willingness to use wooden crates with lining (USE) and perceived net benefits (PNB) on a 5-point Likert scale ranging from (1) 'strongly disagree' to (5) 'strongly agree'. The USE variable is a one-item construct measured by 'I will use wooden crate with lining.' The PNB was measured by the items 'I believe alternative packaging can increase profits,' 'I believe alternative packaging is cost effective, when prices are high (in low season. March–May),' 'I believe alternative

packaging is cost effective, when prices are low (in high season. September–November),' and 'I believe alternative packaging can reduce costs of postharvest losses.' Data were subjected to descriptive analysis and correlation matrix statistical estimations.

6.3 Results and discussion

6.3.1 On-station trial to test effectiveness of applied lining material

The data from the lining material trial did not exhibit significant difference between treatments for fruit that had internal bruising due to lining materials used for storing and transporting tomato (Table 6.1). The percentage of fruit having external bruising exhibited statistically significant differences at the 1% level for paper lining and 10% level for the Hessian cloth material lining between treatments, with the highest being the no lining control treatment and the lowest being the tomatoes in the Hessian cloth–lined crates. However, in the treatment with paper-lined crates, a small minority of the fruit exhibited cuts and/or broken skin. There were no differences in undamaged fruit between the paper lining treatment and the no lining treatment. An approximately 6% to 7% overall reduction in visibly damaged fruit was achieved by packing tomatoes in wooden crates with lining, either Hessian cloth material (reusable but expensive) or brown paper (cheap but reusable once or a limited number of times only).

Table 6.1: Effect of lining of wooden crates on type of damage to tomatoes.

Lining material	Undamaged fruit	Internally bruised fruit	Externally bruised fruit
No lining (STA)	50%[a]	33%	17%
Paper lining (PAP)	58%	33%	11%
Hessian cloth (HES)	53%	34%	10%
p-value$^{STA-PAP}$	0.44	0.93	0.01*
p-value$^{STA-HES}$	0.97	0.43	0.07**
p-value$^{PAP-HES}$	0.24	0.27	0.66

Remark: ANOVA (*p*-value) calculation based on weight data, significant at *p<0.01 or **p<0.10; [a] Average of seven crates each.

Source: Own illustration based on SPSS output.

Information obtained from the market shows that price of marketable tomatoes was lower per 40 kg crate during the peak season than during the off-season (low season), when there is a notable deficit in tomato production. Culled tomatoes can attract less during both seasons (Table 6.2). Net benefits, based on economic cost-benefit analysis, indicated that net profit of tomato packed in wooden crates with paper linings increased a small amount during the off-season. However, due to lower market price during the peak season, no differences were

observed between packaging materials. Although the cost for the Hessian cloth lining material is higher compared to paper, higher net profits per crate than with paper lining can be realized in both season in the long run (Table 6.3).

Table 6.2: Prices for tomato crates at Kilombero market, Arusha.

	Price 1 crate (40 kg) in USD	
Quality	High/Peak Season	Low/Off Season
Good/marketable	4.80 - 12.00	24.00 - 30.00
Damaged/poor quality/culled	0.60 - 4.20	12.00 - 18.00

Source: Results based on survey with four retailers at Kilombero market, Arusha.

Table 6.3: Economic Cost-Benefit analysis of current and new packaging[a].

		Current practice – standard wooden crate	New practice – Paper lining	New practice – Hessian (Asian cloth)
Factor		Tomato collected in standard wooden crates (unlined)	Tomato collected in standard wooden crates lined with perforated brown paper	Tomato collected in standard wooden crates lined with Hessian cloth– reusable
COSTS				
Capital cost (in US$)[b] Standard wooden crate		2.11	2.11	2.11
Lining cost (in US$)			0.24	1.51
Additional cost (in US$)			0.24	1.51
EXPECTED BENEFITS [c]				
% losses [d]		50	44	44
Damaged Tomatoes (*X* kg)		20	17.75	17.75
Good Tomatoes (*X* kg)		20	22.25	22.25
Price crate at market (in US$) [e]	Peak season	5.20	5.52	5.52
	Off season	23.32	24.36	24.36
Net benefit (in US$) [f]	Peak season		0.07	-1.19
	Off season		0.79	-0.48
ROI [g]	Peak season		0.29	-0.79
	Off season		3.29	-0.32

Remark: [a] Exchange rate: US1$ = 1655 TZS as of March 2014; [b] Only those variables that are different when comparing handling practices or technologies; [c] Calculated for one ~40 kg wooden crate. Results calculated based on rounding to two decimal places; [d] Expected changes in percentage of postharvest losses from trial conducted from at AVRDC from 28 to 30 March 2014; [e] Price of crate at market = Damaged tomatoes (*X* kg) x Price/kg for damaged tomatoes + good tomatoes (*X* kg) x Price/kg for good tomatoes; [f] Net benefit = Price for $crate_{PAP/HES}$– Price for $crate_{STA}$–Additional $cost_{PAP/HES}$ for each season; [g] ROI = Net benefit/additional cost.

Source: Adapted from Kitinoja et al. (2010) to the tomato packaging case.

6.3.2 Field-level on-trial survey to assess physical losses at retailer's level

Retailers estimate losses as generally higher, between US$1.20 and US$6.00 (TZS 2000–10,000) per 40 kg crate. Three of the four retailer respondents did not prefer wooden crates for tomato transportation due to fruit damage. Retailers suggested improving wood packaging by reducing the gap between the wood slats in sides of crates or putting a paper lining in the wooden crate. Paper lining reduced losses by the equivalent of approximately half a bucket (3.5 to 4.0 kg) at the retailer level. In monetary terms, retailers can increase their profit by US$1.80–US$2.40 (TZS 3000–4000) during the low season, low production, and high market prices and US$1.20–US$1.50 (TZS 2000–2500) during the high season, high production of tomato, with low market prices, for selling an additional half a bucket.

The cost-benefit analysis indicated that wholesalers and retailers can increase net profits by using paper lining in wooden crates during transportation of tomatoes. The results indicate that though paper lining for standard wooden crates is profitable, adoption rate by traders was low for varied reasons. It is important to understand the perceived reasons, as well as their underlying adoption behaviors and related barriers, other than examined socio-economic factors (Matata et al., 2010; Mbaga-Semgalawe & Folmer, 2000; Nkonya et al., 1997). Notably, adoption of alternative package materials may be influenced and caused by several external factors other than monetary benefits, especially on perceptions of adopters. The following section focuses on trader perceptions with adoption of alternative packing materials, not on the impact of trader perceptions toward adoption of alternative packing materials, which was not within the scope of this project.

6.3.3 Trader survey to understand trader perceptions about alternative packaging material

Wholesalers – Responses by wholesalers from the traders' survey indicated that almost half of respondents disagreed on use of lining materials in wooden crates, a majority agreed, and a few were indifferent. Major assigned reasons for rejecting paper lining include that belief that paper lining was not going to be practical and applicable during the rainy season; lack of awareness, knowledge, and evidence of any success for its use; concerns that paper lining may not be available in villages where tomato are grown; perceived increased handling costs; and lack of certainty that retailers will be willing to buy tomatoes in standard wooden crates with lining materials because tomatoes cannot be visually inspected.

The traders' association typically manages use of wooden crates and decides on the standard size, with individual wholesalers having no responsibility to modify the size of wooden crates.

Adoption of paper lining for wooden crates by traders depends on the traders' association's collective decision. Based on interaction with traders, it was observed that the chairman of the traders' association and some influential traders who were members of the local association strongly influence the opinions and decisions of other traders. Some traders interfered in the course of the interviews and might have somehow intimidated and influenced responses from some respondents.

The Pearson correlation matrix of willingness to implement wooden crates with lining and its perceived net benefits are reported for all categories of traders (Table 6.4). The results indicate that wholesalers have comparatively higher significant correlation coefficients between perceptions of perceived net benefits and willingness to use wooden crates with lining materials, but there were a less significant correlation for village collectors and retailers. For wholesalers, the perceived net benefit might be an important factor for adopting alternative packaging, which might affect adoption of alternative packaging materials.

Village collectors – Because most village collectors use plastic basins for packing and transporting the crops to market, the percent rejecting paper lining for standard wooden crate was high, with nearly half of village collectors disagreeing, about a third being indifferent, and about a fifth agreeing regarding the beneficial effects of paper lining for wooden crates in reducing postharvest losses. Unlike wholesalers who transport produce in specialized big cargo trucks, village collectors usually move produce to markets via regular smaller public transport, at US$1.20 (TZS 2000) per plastic basin, and standard wooden crates are not usually accepted for loading in the trunk of such smaller buses. A traders' association for tomato village collectors does not exist. In addition, they do not have an official trading space at the market. Some female village collectors, who sometimes double as tomato producers, work with their husbands, who trade in standard wooden crates to horizontally integrate in the business. This is because it is culturally believed that the tomato in wooden crates business usually requires huge initial capital investment, which is the domain of men. If a returnable plastic basin is damaged, it has to be replaced at a cost of US$3.60 (TZS 6000). The only notable female village collector dealing with standard wooden crates at the Kilombero market was willing to try the use of paper lining. The Pearson correlation matrix of willingness to implement wooden crates with a lining and its perceived net benefits significantly differed for village collectors because they believed that alternative packaging is cost-effective in the low season, but the same was not observed during the high season. Village collectors voiced the least acceptance due to lower perceived net benefits, followed by retailers. Perceived net benefits might not be the most important variable determining adoption of alternative packaging by village collectors, and other variables influencing non-acceptance need to be examined (Table 6.4).

Table 6.4: Pearson correlation matrix between 'willingness to use wooden crate with lining' and 'perceived net benefit' for tomato trader sample.

	PNB1[a]	PNB2	PNB3	PNB4
Willingness to use wooden crates with lining (USE)	Believe alternative packaging can increase profits	Believe alternative packaging is cost effective when prices are … Low	High	Believe alternative packaging can reduce costs of postharvest losses
USE^{all}	0.434*	0.557*	0.483*	0.436*
USE^{W}	0.429*	0.531*	0.481*	0.450*
USE^{VC}	0.188	0.677**	0.279	0.175
USE^{R}	0.507**	0.463**	0.381	0.434***

Remark: W = Wholesaler, VC = Village collector, R = Retailer, all = Wholesaler + village collectors + retailer; *, **,*** correlated at 0.1, 0.05 or 0.01 significance level (two-tailed); [a] PNB = Perceived net benefit.

Source: Own illustration.

Retailers – The willingness to adopt paper lining in wooden crate packaging tends to follow a different trend at the retailer level due to perceived net benefits. Survey results indicate that a small number of retailers would not buy wooden crates with lining, about 21% were indifferent, and about 74% agreed to buy wooden crates with linings. Retailers who buy tomatoes in plastic basins can only see the top surface level and only buy tomatoes together with the returnable plastic basins. Those retailers evaluated tomato quality as being higher than in standard wooden crates even though they could not see the overall quality during a purchase transaction. Wholesalers felt that retailers would not buy wooden crates with a paper lining because they cannot evaluate the produce visually through the sides of the crate, which was not founded due to retailers buying tomatoes in plastic basins. A knowledge gap exists between wholesalers and retailers regarding evaluation of packaging materials.

Pearson correlation analysis indicated the perception of alternative packaging as being cost-effective in the low season and positively and significantly correlated with perceived adoption of wooden crates with lining by retailers. In the peak season there was no relationship between willingness to adopt alternative packaging and cost-effectiveness. Retailers evaluated perceived net benefits as positively correlated with willingness to adopt wooden crates with lining.

6.4 Conclusion

Improving tomato packaging and handling during packaging, transportation, and selling has potential to decrease postharvest losses and increase availability of good quality tomatoes in the market. Wooden crates with paper lining are a low-input, simple, profitable method to

improve tomato packaging in wooden crates. Underlying factors contributing to rejection or acceptance provide insight to reasons for evaluation by traders. This chapter provides useful insights for further research on tomato packaging to meet requirements of users and avoid perceived risks by traders. Training to improve awareness and knowledge about benefits of packaging materials could change perceptions and might influence adoption of alternative packaging materials such as paper lining in wooden crates. There is a need to collect first-hand market information and underlying behavioral determinants of participant market power decisions before proposing new postharvest handling technologies. Identification of and convincing influential supply chain actors might be critical determinants of success for implementing alternative package materials. Further, the implementation of improved postharvest handling materials depends on the evaluation of the respective chain actor. Therefore, many theoretical models exist in order to analyze individuals' decision making (chapter 2). Thus, the next chapter uses two well-established theoretical models, i.e. Technology Acceptance Model and Theory of Planned Behavior, for determining traders' intention to use improved tomato packaging.

7 Analysis of traders' evaluation of improved packaging based on Technology Acceptance Model and Theory of Planned Behavior

RQ 5: What determines traders' evaluation toward new food technologies exemplified on an improved tomato packaging?

RQ 5.3: What are the main psychological factors driving traders' evaluation of a new type of wooden crate with lining?

RQ 5.4: What are main explanatory factors that affect the psychological constructs of traders' evaluation of improved packaging?

This chapter is based on the following publication:

Kamrath, C.; Rajendran, S.; Nenguwo, N.; Afari-Sefa, V. and Bröring, S. (2018): Adoption behavior of market traders. An analysis based on Technology Acceptance Model and Theory of Planned Behavior. *International Food and Agribusiness Management Review 21 (6):* 771–790*.* DOI: 10.22434/IFAMR2017.0043.

7.1 Introduction

Food losses from waste and spoilage are a fundamental issue, especially in developing countries. On a global level, food losses amount to about one-third of total production (Gustavsson et al., 2011), which places greater strain to increase the cultivation of marginal lands. While this is certainly a global problem, the explanations tend to vary depending on context. For instance, whereas food waste in developed countries mostly occurs at the consumer stage, low-income countries record the highest food losses during the postharvest and processing stages of the food supply chain (Gustavsson et al., 2011). As a potential cause, it has therefore been noted that developing countries lack both the infrastructure and advanced postharvest technology options available to developed countries in order to better handle perishable food (Shewfelt et al., 2014). Even within developing countries moreover, there are various causes of postharvest losses along the food supply chain; for example, the use of inappropriate varieties; use of poor quality packaging material; and inadequate and poor postharvest handling practices (Abass et al., 2014; Affognon et al., 2015; Aidoo et al., 2014; Dome & Prusty, 2016; Kader, 2005; Kasso & Bekele, 2018; Kereth et al., 2013; Kitinoja et al., 2011; Parmar et al., 2017). In spite of their differences, all of these issues influence the physical and quality parameters of the food and can therefore result in loss of market value and diminished incomes for farmers, and particularly smallholders, in developing countries.

Given the prevalence of such problems, the importance of technology development has therefore been highlighted as one broad strategy to reduce postharvest losses in developing countries. Among others, improvements in non-plastic (for example, wood and baskets) packaging through better lining or the usage of plastic crates have both been suggested as a potential solution (Campbell et al., 1986; Eaton et al., 2008; Gustavsson et al., 2011; Kader, 2005; Kamrath et al., 2016; Kitinoja et al., 2011). Nonetheless, the viability of such a strategy is inextricably limited by the slow adoption of novel technologies. In general, adoption has been defined as “a decision to make full use of an innovation as the best course of action available” (Rogers, 1995, p. 177) and is one identified measurement of evaluation (see chapter 1). Hence, there has been a variety of research into how individual decision-making can be explained by psychological constructs such as motivation, attitude, personality (e.g. Ajzen, 1991). What determines the ‘best course of action’ is however not determined by the individual alone. Instead, many social and economic factors have the potential to hinder and influence adoption of improved or new technologies (Affognon et al., 2015; Ali, 2012; Kitinoja, 2013; Tenge et al., 2004; Wasala et al., 2014). Further, it can be expected that the types of factors will significantly differ across socio-economic and cultural groups in developing countries, particularly in countries where there exist social and cultural norms and other related issues that influence the evaluation of new agricultural technologies (Yamano et al., 2015). Thus, it

is invariably necessary to determine which types of factors influence technology evaluation in the specific context that is being explored. For instance, according to Kitinoja et al. (2010), technology evaluation in the context of East Africa is broadly contingent on how much the intended beneficiary perceives there to be a value and a variety of external factors. Regarding the latter, the authors enumerate the relative advantage that is afforded, the compatibility with socio-cultural values, the perceived needs of clients, the complexity of the technology and the potential for actors to make trials with it, and finally the observability of effects and changes.

The major operators in the food supply chain for fresh fruit and vegetables are farmers, traders and consumers (Koenig et al., 2008). Traders generally function as intermediaries between the various actors, and therefore occupy a more or less dominant position. As one potential motivation for technology adoption, traders are likely to benefit from improvements in postharvest handling and practices, which would allow them to provide higher quality produce and increase their profits (Kitinoja et al., 2010). No research about technology evaluation of traders has been undertaken could be identified. Rather, most of the studies in this domain tend to focus on farmers' perspective. In addition, several studies have reviewed the psychological behavior toward evaluation of new technologies at farm level. However, little is known at traders' level about the factors influencing adoption of improved packaging materials, particularly in relation to their psychological constructs. Therefore, addressing evaluation by tomato traders toward postharvest technologies in the tomato value chain is important to reduce losses in the food value chain which ensures better marketing efficiency and serves as a sample design for other studies.

Based on these research gaps, this study investigates two research questions:

- What are the main psychological factors driving traders' evaluation of a new type of wooden crate with lining?
- What are the main explanatory factors that affect the psychological constructs of traders' evaluation of improved packaging?

Against this background, this chapter seeks to contribute to the existing literature in two aspects: (i) to understand technology evaluation in the specific context of tomato packaging for those traders who are prominently involved in the tomato value chain and (ii) to offer complementary insights in order to improve the general understanding of this area as well as to facilitate methodological and theoretical development of technology evaluation in

developing countries in the agricultural sector. For this reason, this study adopted the Arusha region of Tanzania in order to explore these research questions.

7.2 Review of literature on adoption behavior in developing countries

The following section describes the evaluation of new technologies in developing countries particularly focusing on postharvest handling techniques.

7.2.1 Evaluation of new technology in developing countries in agricultural context

The high level of postharvest losses caused by mechanical damage that often facilitates incidence of diseases indicates the importance of the adoption of improved postharvest handling techniques. It is particularly applicable for a highly perishable crop like tomato (Aba *et al.*, 2012).

At the farmer level, the factors affecting evaluation of different technologies and improved agricultural practices have been analyzed (Afari-Sefa et al., 2016; Affognon et al., 2015; Agwu et al., 2008; Aidoo et al., 2014; Ali, 2012; Feder et al., 1985; Hodges et al., 2011; Isgin et al., 2008; Lazaro et al., 2017; Tenge et al., 2004). The main observed factors that determine farmers' evaluation of recommended practices in existing studies mainly include socio-economic factors such as age, gender, education, experience (Agwu et al., 2008; Hansson et al., 2012), income, lack of access to credit (Aidoo et al., 2014; Namara et al., 2014), farm size (Adrian et al., 2005; Isgin et al., 2008; Nkonya et al., 1997), knowledge and perception of technology and net benefits accrued from application of recommended practices (Adesina & Baidu-Forson, 1995; Adrian et al., 2005; Mbaga-Semgalawe & Folmer, 2000), and further the underlying psychological construct, i.e. attitudes toward new technology, social norms and perceived behavioral control (Hansson et al., 2012; Yamano et al., 2015; Yazdanpanah et al., 2014), which are adapted from Ajzen (1991). Some studies argued that the behavior of actors within the value chain has the potential to promote more sustainable technologies that can reduce postharvest losses (Hodges et al., 2011; Parmar et al., 2017).

7.2.2 Overview of the current tomato value chain in Tanzania

As it is the case for many developing countries, the tomato is an important horticultural crop in Tanzania, both for home consumption and as a major cash crop with the potential for poverty reduction (Koenig et al., 2008). In spite of its potential benefits, however, tomatoes are very vulnerable to food losses and spoilage due to their high water content, high respiration rate, and soft texture (Isack & Lyimo, 2015). Accordingly, some of the major challenges in the rather

complex and opaque tomato supply chain (Mwagike & Mdoe, 2015), include: poor transportation facilities (i.e. reliance on feeder roads where travel is difficult), lack of market infrastructure facilities (e.g. lack of cold storage), rough and poor postharvest handling practices, as well as poorly constructed packaging materials and use of open trucks to transport produce over longer distances. Currently, the type of packing materials used by wholesalers are rough wooden crates that hold around 40 kg and are mainly used to transport tomatoes in Arusha, Tanzania. This explains the high share of tomato losses caused by bruises and cuts (Kamrath et al., 2016)[19], numerical 30 to 40% per crate in developing countries (Kader, 2005; MUVI-SIDO, 2009). In order to cultivate a shift in this value chain however, it is necessary to understand who bears the responsibility for any risks and, moreover, who it is that makes decisions about packaging materials. Overall, it is the case that a number of different channels of the tomato value chain exist in Tanzania (for detailed description and visualization, see Koenig et al., 2008. Nevertheless, it is generally the traders who buy tomatoes from farmers and then sell them at markets who are mostly responsible for transportation and must therefore incur any related risks (Koenig et al., 2008; Mwagike & Mdoe, 2015). As a result, wholesalers are broadly influential for the approaches and types of packaging that are used. Nonetheless, it must also be noted that any initial packaging is generally done by the farmers, and wholesalers or village collectors who are responsible for the transport and selling the produce at the market (Koenig et al., 2008; Mwagike & Mdoe, 2015). Facilitating changes in the tomato value chain therefore requires attention to the (joint) decisions of both traders and farmers.

Kamrath et al. (2016) (chapter 6) concluded that perforated paper lining is the simplest and most cost-effective improvement for use with the traditional rough wooden crates for tomato packaging. The authors further argued that recommended improvements were not adopted by supply chain actors due to lack of awareness, knowledge and evidence of any success for its use. But further results have shown that willingness to use is positively correlated with perceived net benefits.

Accordingly, this study specifically focuses on the decisions of tomato traders, given that such actors not only occupy an intermediate and mostly dominant position in value chains, but are also the ultimate beneficiaries of any efficiency gains in postharvest handling and practices (Kitinoja et al., 2010; Musebe et al., 2017). In general, most of the transactions between farmers and ‘middlemen’ (i.e. those who connect local farmers and regional markets) are based on spot-market negotiations whereby traders enjoy most of the bargaining power

[19] Results of Kamrath et al. (2016) are presented in chapter 6.

(Mwagike & Mdoe, 2015). In addition, when traders engage in further purchases directly at the farmgate, they must then, in their role as middlemen, organize their own transport and packaging for the produce. As such, it is the traders who determine which type of postharvest handling practices are employed. Generally smallholders, having no or limited access to higher-value markets such as supermarkets, are therefore subject to being exploited by middlemen (Chagomoka et al., 2014). Accordingly, it is potentially problematic to focus only on farmers when it comes to adoption decisions about new technologies. Given that farmers ultimately lack strong bargaining power in the tomato supply chain in developing countries (Koenig et al., 2008), this study therefore takes the unique approach of focusing on the evaluation of traders vis-à-vis improvements in postharvest handling practices.

7.3 Conceptual framework and development of hypotheses

In order to address the gaps in the current research landscape of the adoption behaviors of traders, two well-known and widely applied behavior theories are chosen, i.e. both of which are based on the Theory of Reasoned Action (TRA). The TRA (see also section 2.3.3) is extensively used to explain human behavior and asserts that both behavioral attitude (A) and subjective norm (SN) affect behavioral intention (BI), which in turn affects actual behavior. The Theory of Planned Behavior (TPB) differs from the TRA in its addition of perceived behavioral control (PBC) as an influencing factor on behavioral intention (Ajzen, 1985). Together with behavioral intention, PBC can be used directly to predict actual behavior (Ajzen, 1991). The TPB is a general model to analyze human behavior and it has been applied mainly to study technology adoption behavior and use in several cases (Mathieson, 1991); particularly few studies have applied this theory in the agricultural context more so at smallholder farmers' supply chain level in developing countries (Hansson et al., 2012; Senger et al., 2017; Yamano et al., 2015; Yazdanpanah et al., 2014), but not at traders' level.

In general, analyzing technology adoption and use specifically, the Technology Acceptance Model (TAM) was developed in the context of Information Technology Systems (inter alia: Holden & Karsh, 2010; Lee et al., 2003; Legris et al., 2003; Venkatesh & Davis, 2000; Venkatesh et al., 2007) and its importance and extensive application examined in technology-driven oriented sectors (inter alia: Holden & Karsh, 2010; Lee et al., 2003; Legris et al., 2003; Venkatesh & Davis, 2000; Venkatesh & Morris, 2000; Venkatesh et al., 2007), but has also been applied in the context of new agricultural technology evaluation at farmers' level in the context of precision agriculture in southeastern United States (Adrian et al., 2005) and of dairy farming in New Zealand (Flett et al., 2004). The TAM, originally introduced by Davis et al. (1989), is an adaptation of TRA and assumes that the acceptance of information technology

is determined by two key beliefs: perceived usefulness (PU) and perceived ease of use (PEOU) (Davis et al., 1989; Morris et al., 2005).

TAM and TPB have different emphases but both are extensions of the TRA, which makes the inclusion of TAM and TPB rational, theoretically compatible and potentially complementary. PEOU and PU by TAM may serve as important antecedents of attitude in TPB, which reciprocally may enhance the explanatory power of TAM (Chau and Hu, 2002; Mathieson, 1991). In this chapter, TAM is used to identify the usefulness and ease of use of the standard wooden crate covered by paper lining (improved packaging, for more detail: Kamrath et al., 2016), and further the variables attitude toward using (A), SN and PBC by TPB might give insight to factors disturbing the BI of new technology (Figure 7.1). Thereby PEOU and PU may serve as important antecedents of A. Each determinant will be influenced by explanatory variables, which help to understand the psychological construct underlying evaluation.

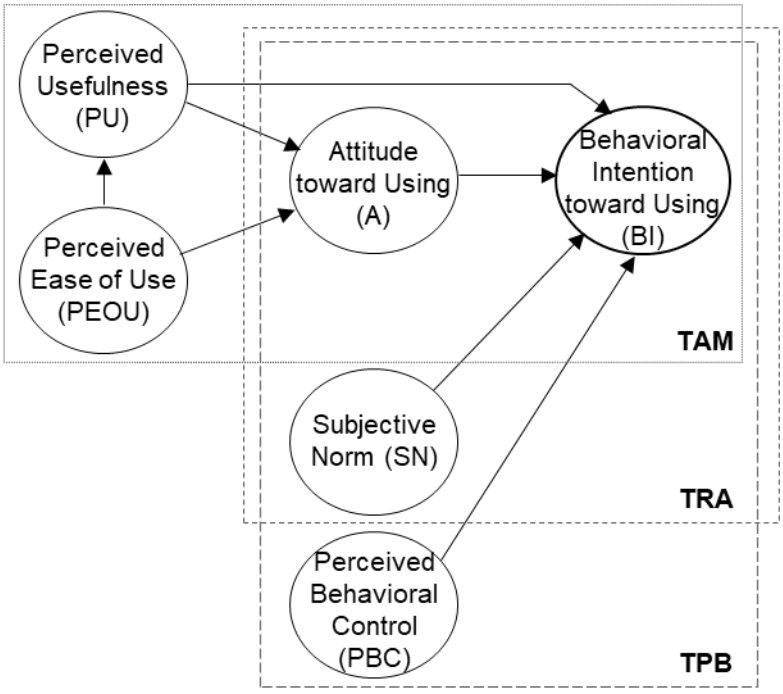

Figure 7.1: Combined research model of TAM and TPB.

Remarks: TAM = Technology Acceptance Model; TRA = Theory of Reasoned Action; TPB = Theory of Planned Behavior.

Source: Ajzen (1991); Davis (1986); Fishbein & Ajzen (1975).

Based on the theoretical framework, a set of seven hypotheses is derived, which are detailed in the following. Attitude (A) is defined by Ajzen (1991) as the degree to which a person has a favorable or unfavorable evaluation of the behavior in question. According to TAM and TPB, the attitude toward using a new technology impacts users' behavioral intention. Transferred to

the case of improved tomato packaging, it is when supply chain actors form a positive attitude toward an improved packaging, they will have a stronger intention toward adopting it, and thus they are more likely to use it. The first hypothesis of this study is:

H_1: Behavioral attitude toward improved packaging is positively related to the behavioral intention to use improved packaging.

Not only the relationship between A and BI is fundamental to TRA and adapted in the TAM, but also the direct effect of a belief (such as PU) on BI (Davis et al., 1989). PU, i.e. the extent to which using a technology will improve productivity, and PEOU, i.e. the extent to which using a technology will be free of effort, are the two key beliefs of TAM (Davis et al., 1989). The major beliefs are that PU and PEOU will affect a user's attitude. According to the trader respondents in this study, evaluation depends on the usefulness (PU) and easiness of use (PEOU) of new packaging material for improvement of their business operations. Thereby 'usefulness' in this context means if traders believe that the improved packaging improves the job performance and will be beneficial to them. It is assumed that a better job performance will influence the attitude toward produce packaging positively. Additionally, the more complex it is to use the improved packaging, the less positive traders will evaluate the packaging. The second and third hypotheses of this study are as follows:

H_2: Perceived usefulness is positively related to attitude toward improved packaging.

H_3: Perceived ease of use is positively related to attitude toward improved tomato packaging.

Further, it is argued that the more traders value improved packaging as easy to use, the more useful they consider the improved packaging technology. This hypothesis is adapted from the original theory by Davis et al. (1989). Therefore, fourth hypothesis of this chapter is:

H_4: Perceived ease of use is positively related to perceived usefulness of improved tomato packaging.

Additionally, TAM specifies a causal effect of PEOU on PU, so that behavioral intention will be indirectly affected by PEOU through PU (Davis et al., 1989). Therefore, it is assumed that the easier it is for a trader to recognize an improvement in produce packaging, the more useful the trader will find the improved packaging option. Further it is assumed, that traders are more likely to adopt the proposed improved packaging when perceived usefulness and ease of use is high. The following hypotheses are thus formulated:

H_5: Perceived usefulness is positively related to behavioral intention to use improved packaging.

According to TPB, SN refers to the belief by users that their neighbors and/or fellow group members would evaluate them positively (or negatively) if they behaved in a certain way (Ajzen, 1991). Group members might consist of family, similar ethnic group, social group, friends, opinion leaders or people in authority, each of whose beliefs are likely to be influential and important to the individual. In this regard, it is crucial to understand how members of one's peer group can determine individual intentions. Notably, the opinions of others are likely to prove especially influence at the early stages of new technology adoption, given that it is exactly at this point where the individual decision-maker has the least experience with the technology and is therefore likely to be more susceptible to the reactions and input from important members of his or her peer group. In other words, it is for such reasons that the direct effect of SN on BI is likely to be highly significant and positive (Venkatesh & Morris, 2000). Based on a similar assumption, Kamrath et al. (2016) found that less experienced traders might be influenced in their opinions and decisions by more powerful peer members in the group, i.e. more experienced traders and the chairman of the traders' association of the tomato supply chain in the Arusha region of Tanzania. This suggests that the influence of peer members who are most influential in decision making, will have an impact on trader's intention to use improved packaging, therefore this chapter hypothesized that:

H_6: Subjective norm will have a positive effect on the behavioral intention to use improved packaging.

Further, perceived behavioral control (PBC) is defined as the perceived ease or difficulty of performing the behavior (Ajzen, 1991). This means an individual is perceived to have the necessary resources, capability, and a sense of control in successfully performing the behavior (Lu et al., 2009). The PBC can influence behavior directly or indirectly through BI. Although the improved packaging 'wooden box with lining' is an improved technology, which is relatively easy to use, users still need to know where they can get the resources (paper lining). Furthermore, traders need to understand the economic benefits and how to implement those improved boxes in the tomato supply chain. Thus, it is posited that:

H_7: Perceived behavioral control is positively related to the behavioral intention to use an improved packaging.

In the context of this chapter, it could be also argued that PU and PEOU invariably influence PBC on the adoption of the improved packaging. The more useful the traders perceive the new packaging technology, the easier it will be for them to get associated with it and manage its implementation. However, no relevant literature to support this anticipated relationship could be found.

Table 7.1 summarizes the operational definition of the constructs and Table 7.2 represents an overview about the hypotheses within the proposed research model.

Table 7.1: Definitions of latent constructs within TAM+TPB model.

Variable	Construct	Operational Definition
BI	Intention to use packaging	An individual's behavioral intention to use improved packaging
A	Attitude toward Using	An individual's overall evaluation toward using improved packaging
SN	Subjective Norm	Users' perception of whether peers within their group perceive they should use improved packaging
PBC	Perceived Behavioral Control	Users' perception if they have the necessary resources and capability in successfully using improved packaging
PU	Perceived Usefulness	An individual's perception that using improved packaging will enhance job performance
PEOU	Perceived Ease of Use	An individual's perceived exerted efforts when using improved packaging

Source: Adapted from Ajzen (1991) as well as Davis (1986) and adapted to corresponding context.

Table 7.2: Hypotheses of TAM+TPB model.

Relationship		Hypotheses
A → BI	H_1	Behavioral attitude toward improved packaging is positively related to the behavioral intention to use improved packaging.
PU → A	H_2	Perceived usefulness is positively related to attitude toward improved packaging.
PEOU → A	H_3	Perceived ease of use is positively related to attitude toward improved tomato packaging.
PEOU → PU	H_4	Perceived ease of use is positively related to perceived usefulness of improved tomato packaging.
PU → BI	H_5	Perceived usefulness is positively related to behavioral intention to use improved packaging.
SN → BI	H_6	Subjective norm will have a positive effect on the individual's intention to use improved packaging.
PBC → BI	H_7	Perceived behavioral control is positively related to the behavioral intention to use an improved packaging.

Source: Own illustration.

7.4 Materials and methods

7.4.1 Study area and sampling approach

To explore the evaluation of novel technologies more broadly, this study focuses on the decisions of traders within the tomato value chain. Conducted in the Arusha region of Tanzania in June, 2014, the analysis in this chapter uses a sample of 80 traders. This sample of trader comprises of 19 retailers, 13 village collectors and 48 wholesalers based on the data presented in chapter 6. The data collection method is detailly described in section 6.2.3.

7.4.2 Measurement of psychological constructs

Psychological constructs are non-observable, also known as latent constructs (DeVellis, 2016) and are represented by measurable observable (either formative or reflective) indicators (Hair et al., 2014). In order to measure the latent constructs, the following reflective items (see Table 7.3) have been deduced from extensive literature (Adrian et al., 2005; Davis, 1986; Davis et al., 1989; Hansson et al., 2012; Venkatesh & Bala, 2008; Yazdanpanah et al., 2014). Thus consistent with previous studies on technology evaluation, the six psychological latent constructs (Table 7.3) were applied into the research context of the improved tomato packaging materials in the Arusha region of Tanzania, which were measured on a five-point Likert scales, ranging from (1) 'strongly disagree' to (5) 'strongly agree' to operationalize the constructs BI, A, PU, PEOU, SN and PBC with the exception of the item BI4. Answer options of BI4 ('will make effort to switch to the wooden crates with lining') are (1) never, (2) by the next year, (3) by the next month, (4) by the next week and (5) by the next day. Table 7.3 summarizes the constructs of the research model and its source. The second part of the questionnaire focused on respondents' demographics and socio-economic characteristics, trading activities, marketing infrastructure and social capital.

7.4.3 Analytical framework

The variance which is based on the Structural Equation Modeling (SEM) approach using partial least squares (PLS) was used to analyze the relationship among variables by applying SmartPLS 3 software package. For detailed explanation on PLS-SEM please refer to section 4.3.3. In general, SEM is designed to test theoretical models, and in particular some studies have applied this method for testing theories such as TPB and TAM (Aboelmaged, 2010; Chen & Chao, 2011; Lu et al., 2009; Nasri & Charfeddine, 2012).

In sum, PLS-SEM is used for the combined model of TAM and TPB with PU, A and BI as endogenous (dependent) and PEOU, SN and PBC as exogenous (independent) variables that are key determinants for dependent constructs. The direct relationships between latent constructs, unobserved variables represented by measurable variables, are considered as an inner model. PEOU is further considered as having a mediator effect through PU to A, also known as an indirect effect that means the relationship involves at least one intervening construct (Hair et al., 2013). The outer model is determined by reflective measured variables. According to the required sample size, the maximum number of arrows is pointing at BI (4 arrowheads). According to Hair et al. (2013) based on Cohen (1992), to achieve a statistical power of 80% for detecting R^2 values at least 0.25 (with a 5% probability of error), the recommended sample size should exceed 65 observations with four arrowheads pointing at BI. Thus the 80 observations in this study exceed the threshold amount.

For this chapter, a two-stage approach was applied for evaluation, following the guidelines suggested by Hair et al. (2013): (i) evaluation of reflective measurement model (outer model, see section 7.5.2); (ii) assessment of structural model (inner model) and hypothesis test (see section 7.5.3).

Due to the small sample size of the sub groups, all three subsamples are treated as a homogeneous trader group. This is supported by further statistical tests (FIMIX procedure as well as Kruskal-Wallis-Tests), lacking identification of significant moderating effects to explain group segmentation.

Table 7.3: Constructs, items and statements for TAM+TPB model.

Latent variables	Manifest Variables		Source
Perceived Usefulness	PU1	I believe that wooden crate with lining can be useful to me as a trader	Adrian, et al. (2005)
	PU2	Using the wooden crate with lining will improve my job performance of tomato transportation/ *of tomato seller*	Davis, et al. (1989)
	PU3	I believe that using wooden crate with lining can improve the quality of my work/ *tomatoes*	Davis, et al. (1986)
	PU4	For me, the wooden crate with lining is more beneficial than the standard wooden box	New
	PU5	Overall, I find the wooden crate with lining practical in my job	Davis, et al. (1986)
Perceived Ease of Use	PEOU1	It is easy and understandable for me to learn how to use the wooden crate with lining/ *how paper lining will reduce postharvest losses and increase tomato quality*	Adrian, et al. (2005)
	PEOU2	For me, it will be easy to put lining in the wooden crate / For me, it will be ease to change to the wooden crate with lining	New
	PEOU3	Overall, wooden crate with lining will be easy to use	Adrian, et al. (2005)

Latent variables	Manifest Variables		Source
Behavioral Attitude	A1	For me, it is important to reduce postharvest losses of tomato during transportation	New
	A2	I think that our trader communities are responsible for reducing postharvest losses during transportation	New
	A3	I believe it is necessary to improve tomato packaging	Yazdanpanah, et al. (2014)
	A4	To run my business efficiently, I need to use/ *to buy* the wooden crate with lining	Hansson, et al. (2012)
	A5	I could consider using/ *buying* the wooden crate with lining instead of the standard wooden crate	Hansson, et al. (2012)
	A6	The best thing for me would be to reduce postharvest losses through tomato packaging with lining	Hansson, et al. (2012)
	A7	I like to try using/ *buying* the wooden crate with lining	Hansson, et al. (2012)
Subjective Norm	SN1	If I implement / *buy* the wooden box with lining, people who are important to me would support it	Yazdanpanah, et al. (2014)
	SN2	Most people who are important to me think that implementing/ *buying* wooden crate with lining is desirable	Yazdanpanah, et al. (2014)
	SN3	People whose opinions I value, prefer that I use/ *buy* wooden crate with lining	Venkatesh & Bala (2008)
	SN4	Others traders asks my advice	New
	SN5	Other traders/*retailer* believe that I adopt new technology/ packaging (that will be used for reducing postharvest losses)	New
Perceived Behavioral Control	PBC1	If I wanted to, I could easily implement/ *buy* wooden crate with lining	Yazdanpanah, et al. (2014)
	PBC2	It is mostly up to me whether or not I implement/ *buy* wooden crate with lining	Yazdanpanah, et al. (2014)
	PBC3	For me, it is not difficult to implement wooden crate with lining	Yazdanpanah, et al. (2014)
	PBC4	I can influence in the tomato value chain needed for implementing the wooden crate with lining	New
	PBC5	In my opinion, it is possible to implement the wooden crate with lining in the tomato supply chain	Yazdanpanah, et al. (2014)
	PBC6	The wooden box with lining is compatible with the old system of the standard wooden boxes	Holden & Karsh (2010)
Behavioral Intention	BI1	I think I will intend using/ *buying* wooden crates with lining for tomato transportation	Yazdanpanah, et al. (2014)
	BI2	My intention to switch from the standard wooden crates to wooden crates with lining is strong	Chen & Chao (2011)
	BI3	The likelihood of my switching to wooden crates with lining is high	Chen & Chao (2011)
	BI4	I will make an effort to switch to the wooden crates with lining by the [choose]	Chen & Chao (2011)
	BI5	I will use/ *buy* wooden crate with lining	Various

Remark: Words in *italic* are different formulations in questions for retailers in comparison to wholesalers and village collectors.

Source: Own illustration.

7.5 Results

7.5.1 Background of tomato traders and their role in tomato packaging

The survey results (Table 7.4) show that most of the traders in the sample are men and have been engaged in tomato trade for an average of 15 years, and mostly used standard wooden

crates (STA) without any lining material. Alternative packaging are plastic basins that are mostly used by village collectors. No trader had experience in the use of lining material for the standard wooden crates. About 45% of the traders answered yes for the question on the willingness to implement/buying wooden crates with lining. Concerns were usage during the rainy season and the availability of the lining in villages where tomatoes are grown.

Table 7.4: Trader characteristics.

Independent variables	Option	
Age (in years)	Average age	41
Gender (in %)	Female/ Male	34%/ 66%
Trader experiences (in years)	General, average	16
	tomato trader, average	15
Using/ Buying STA[a] (in %)	Yes / No/ Undecided	85% / 15%/ 0%
Using/ Buying Lining for STA already (in %)	Yes / No/ Undecided	0% / 100%/ 0%
Willingness to Use STA+Lining (in %)	Yes / No/ Undecided	45% / 38%/ 17%

Remark: [a] STA=Standard wooden crate; [b] Missing % to fulfil 100% are missing respondents.

Source: Data based on survey in June, 2014 at Kilombero Market, Arusha.

7.5.2 Results and evaluation of reflective measurement model

The outer model is determined from reflective measured constructs, because the items of each latent variable are highly correlated and interchangeable (Hair et al., 2013). The PLS-SEM algorithm could find a stable solution within six iterations (Table 7.5). For the explanation and tresholds of the different reflective measurement model evaluation criteria, please refer to section 4.4.3 (and also Hair et al., 2014).

Convergent validity – First, the convergent validity was tested, based on two measurements – the outer loadings of the indicators and the average variance extracted (AVE) values. According to the results presented in Table 7.5, both criteria are met for all latent constructs.

Internal consistency reliability – Both, Cronbach's alpha and composite reliability were used to assess internal consistency reliability. According to Table 7.5, PEOU, A and PBC are internal consistent reliable constructs, but PU, SN and BI lack on internal reliability due to the fact that respondents perceived the questions posed to them to be similar for each latent variables. Thus, deleting the items PU1, PU2 and further SN2 as well as BI2 and BI3 solved the problem for the constructs PU, SN and BI.

Discriminant validity – Finally, the discriminant validity was evaluated with the Fornell-Larcker criterion. The correlation matrix shows that constructs are discriminant valid except between the latent constructs PEOU and A (Table 7.6). As the correlation of PEOU on A (0.887)

exceeds the square root of AVE of the construct A (0.857) only slightly, both constructs are kept for further analysis. The questionnaires of PEOU and A differ and measure different latent perspectives, therefore merging both constructs is not suggested.

Table 7.5: Results summary of reflective measurement models for TAM+TPB model.

Variables	Indicators	Loadings[a]	Cronbach's alpha[b]	Composite reliability[b]	AVE[c]
Perceived Usefulness	PU1	0.950	0.957	0.967	0.854
	PU2	0.957			
	PU3	0.927			
	PU4	0.889			
	PU5	0.894			
Perceived Ease of Use	PEOU1	0.835	0.871	0.921	0.796
	PEOU2	0.908			
	PEOU3	0.931			
Attitude	A1	0.782	0.940	0.951	0.735
	A2	0.745			
	A3	0.799			
	A4	0.910			
	A5	0.911			
	A6	0.928			
	A7	0.904			
Subjective Norm	SN1	0.931	0.940	0.955	0.809
	SN2	0.958			
	SN3	0.940			
	SN4	0.753			
	SN5	0.900			
Perceived Behavioral Control	PBC1	0.845	0.920	0.938	0.716
	PBC2	0.715			
	PBC3	0.839			
	PBC4	0.887			
	PBC5	0.891			
	PBC6	0.887			
Behavioral Intention	BI1	0.907	0.958	0.967	0.856
	BI2	0.954			
	BI3	0.944			
	BI4	0.912			
	BI5	0.907			

Remark: [a] Treshold ≥ 0.708; [b] Treshold ≥ 0.7; [c] AVE=Average variance extracted, treshold ≥ 0.5 (Hair et al., 2013).

Source: Output of SmartPLS 3 (PLS-SEM) based on research sample.

Table 7.6: Discriminant validity for TAM+TPB model.

	A	BI	PBC	PEOU	PU	SN
A	0.857					
BI	0.590	0.925				
PBC	0.768	0.762	0.846			
PEOU	0.887	0.469	0.736	0.892		
PU	0.816	0.586	0.669	0.770	0.924	
SN	0.696	0.713	0.730	0.667	0.622	0.899

Remark: Treshold for Fornell-Larcker Criterium to indicate discriminant validity: √AVE > correlation with other constructs (Hair et al., 2013).

Source: Output of SmartPLS 3 (PLS-SEM) based on research sample.

7.5.3 Assessment of structural model

After assessing reliability and validity, the structural equation model is evaluated to assess the impact of TAM and TPB constructs on acceptance behavior by means of Smart PLS3. Testing the hypotheses, if path coefficients are significant, the bootstrapping procedure with 5,000 subsamples, a significance level of 0.05 and on basis of a two tailed test was run. Results are shown in Figure 7.2 and Table 7.7. For the explanation and tresholds of the different criteria to assess the structural model results, please refer to section 4.4.4 (and also Hair et al., 2014).

Multicollinearity assessment – First testing for multicollinearity problems, VIF values ranged from 1.000 (PU) and 4.126 (BI), indicating that the results were not negatively affected by collinearity.

Coefficient of variance (R^2) – The variance of the endogenous variables PU (0.585) and BI (0.619) in the proposed structural model are explained moderately and A (0.824) has a substantial R^2 value.

f^2 effect size – The predictors PU (0.026), A (0.043) and SN (0.107) contribute relatively little explanation to the R^2 value of BI based on f^2-values. In accordance with the rules of thumb for the f^2, the effect size of PBC (0.335) can be nearly considered as large. Therefore, PBC has highest explanation impact on BI. The variance of A is mainly explained by PEOU (1.029) not so much by PU (0.208). PEOU (1.411) has large effect on the R^2 value of PU.

Cross-validated redundancy (Q^2) – The Q^2 of all three endogenous constructs A (0.599), BI (0.508) and PU (0.488) have larger values than zero after the blindfolding procedure, which implies that the model has predictive relevance for these constructs.

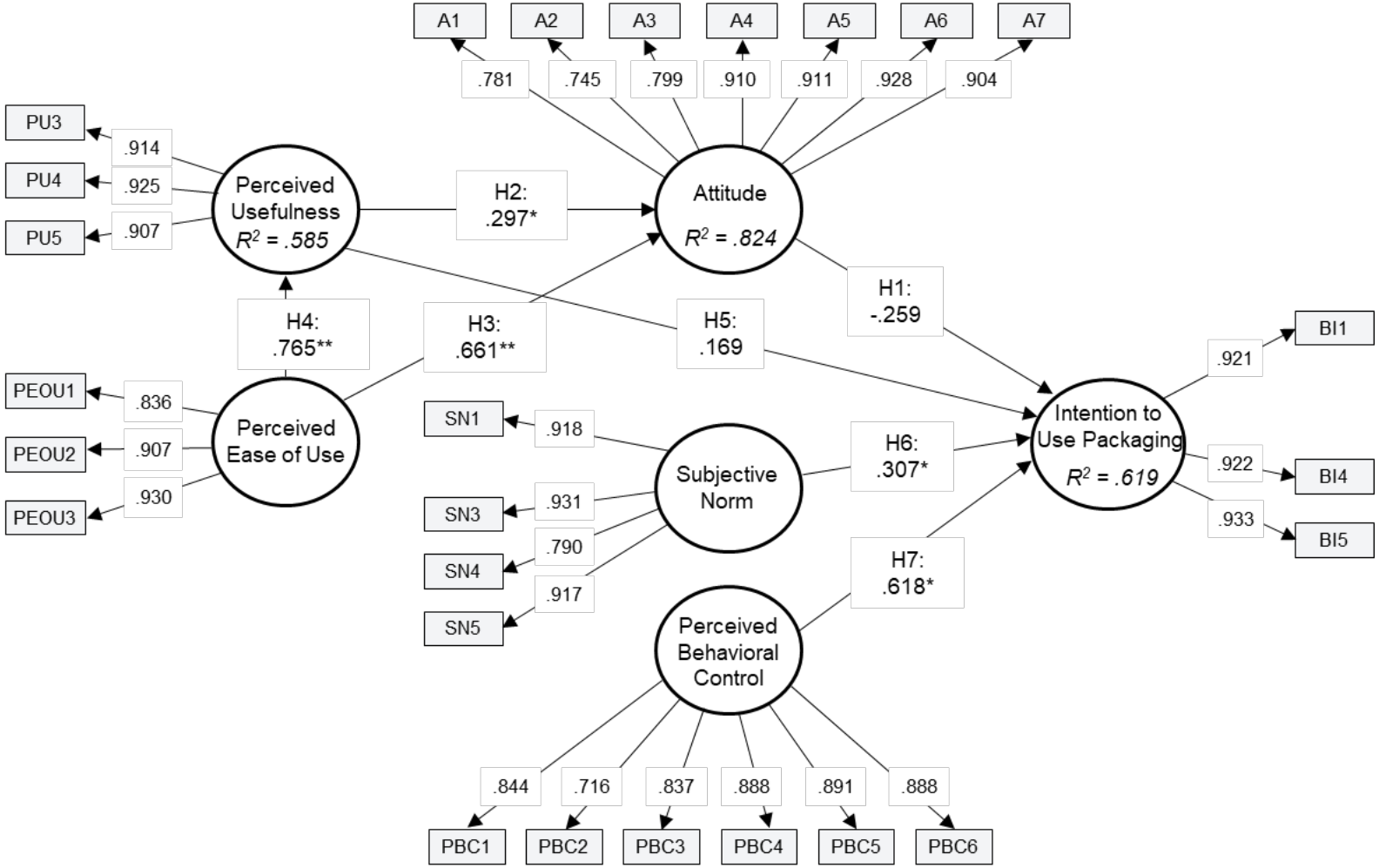

Figure 7.2: PLS path coefficients and bootstrap statistics for TAM+TPB model.

Remark: Outer Loadings = Between manifest variable and latent construct; Path Coefficient = Between two latent constructs, *p < 0.05, **p < 0.01; R^2-values ≥ 0.75, 0.5, 0.25 indicate substantial, moderate and weak explanatory power; PLS-SEM with maximum 300 iterations and stop criterion at 10^{-7}.

Source: Own illustration based on SmartPLS 3 output.

The path coefficients – Considering first the endogenous construct BI, the most influencing factor is PBC (0.618). The hypothesis H_7 can be confirmed at a 5%-significance level in the context of the adoption of wooden crates with paper lining (Figure 7.2). In other words, traders who think they can implement the wooden crate with lining material do have a higher intention to switch to the wooden crates with lining.

The hypothesis H_6 receives support by the study about adoption of wooden crates with lining. At a significance level of 5%, traders who perceive that other important people would support him/ her to use improved packaging are more likely to switch to the wooden crates with lining and is the second most important factor influencing BI.

The hypotheses H_1 and H_5 need to be rejected as the relationships are not significant. Both relationships are well examined in the literature in other contexts (inter alia: Aboelmaged, 2010; Hansson et al., 2012; Mathieson, 1991; Nasri and Charfeddine, 2012), but in this study A and PU do not have a significant effect on BI. The hypothesis H_2 is supported at the 5%-significant level. Therefore, it is supported that the more traders evaluate the packaging as useful the more they have a positive attitude toward the wooden crates with lining. PEOU is for both constructs A and PU a highly significant influencing factor. Thus, hypotheses H_3 and H_4 are supported and confirm that easiness of use contributes positively to usefulness and attitude. Further, PU has a mediating effect between PEOU and A (see Table 7.7).

Table 7.7: Significance testing results of the structural model path coefficients for TAM+TPB model.

	Relationship	**Direct Effect**	**Total Effect**
H_1	A→BI	-0.259	-0.259
H_2	PU→A	0.297*	0.297*
H_3	PEOU→A	0.661**	0.887**
H_4	PEOU→PU	0.765**	0.765**
H_5	PU→BI	0.169	0.092
H_6	SN→BI	0.307*	0.307*
H_7	PBC→BI	0.618*	0.618*

Remark: *$p < 0.05$, **$p < 0.01$.

Source: Results of bootstrapping procedure with SmartPLS 3 based on research sample.

7.6 Discussion, implications and limitations

This chapter used a combined model of TAM and TPB to explore how underlying psychological constructs can explain the decisions of traders to change from conventional wooden crates to wooden crates with a new lining material. The application of this novel framework allows to derive new insights for this context.

Furthermore, use of this combined theoretical approach to explain adoption behavior of new packaging is supported by the moderate (PU, BI) and substantial (A) values for R^2. Overall, there is good model fit, as demonstrated by the f^2 and Q^2 effect sizes. In addition, both perceived behavioral control and subjective norm are shown to strongly predict the behavioral intentions of traders. No significant effect is found however for the influence of attitude toward the packaging. Moreover, from the results, it is able to ascertain that both social network and the distribution of power in value chains and market structures are responsible for the successful implementation of new packaging, not to mention the overall perception of the technology. These findings were also underlined by observation of market activities at the time of data collection. For instance, it was observed that the Chairman of the Kilombero Market Association, i.e. the leader of the local organization of tomato traders, played a crucial and pervasive role in the market place. The trader association and the Chairman determined who would have access to the market and more generally exerted an influence on traders' knowledge and opinions. In this regard, the significant effect of subjective norms can also be explained by the higher complexity of social and business networks and the greater willingness by traders to collaborate. This is perhaps best exemplified by the fact that most wholesalers were members of the Kilombero Market Association. Further, many traders bring their own crates when going to the farmgate to buy tomatoes from farmers. This indicate that traders have a certain level of resources (Parmar et al., 2017), contributing positively to the significant effect of perceived behavioral control. On the other hand, it must be noted that the characteristics of the social structure can broadly differ across African countries. Taking the example of Ghana, it is actually the female 'market queens' who generally have the most power in the tomato supply chain (Lyon, 2003).

In addition, explanatory variables such as the characteristics of traders, type of packaging, network, trading patterns, profit and transportation issues, were not however generally predictive of adoption behavior of traders. In part, this can perhaps be explained by the small sample size in this study. In general, however, the importance of socio-economic factors (e.g. gender) for technology evaluation is both well-known and broadly established by several studies (e.g. Abass et al., 2014; Affognon et al., 2015; Aidoo et al., 2014; Ali, 2012; Feder et al., 1985; Tenge et al., 2004). For this reason, it seems safe to assume that these factors are also likely to be relevant in the context of trader adoption decisions.

The significant relationship between perceived usefulness and attitude seems to contradict the insignificant relationship between A and BI, as well as that between PU and BI. If a person has more positive views about the usefulness of packaging, this is found to strengthen the positive attitude of the improved packaging. However, results are not able to find support for either a further effect of these factors on behavioral intention or for the direct relationship

between perceived usefulness and behavioral intention. This lack of significance could perhaps be attributed to the fact that, while traders like the idea of reducing losses by improving packaging, they do not necessarily have confidence in the practical use of the packaging to improve the shelf life of produce. This could be, for instance, because the viability of the new lining has not yet been demonstrated for the rainy season. Another reason could be that traders are reluctant to change and would instead prefer to retain the business-as-usual approach. Indeed, such reluctance was rather apparent from the field observations. Furthermore, traders might expect, and indeed require, higher returns on investments in return for adopting new lining technology. However, due to the oligopolistic behavior of traders, and wholesalers in particular, there could be a tendency for traders to lack a feeling of responsibility for losses that are incurred in marketing, which they might instead pass along to farmers and others. As a result, the incentive to change their behavior is likely to be low even if their expressed attitudes and intentions to do so are high (e.g. Lagerkvist et al., 2013). Accordingly, the more careful the traders are, the more they need to be convinced of the potential returns from technology adoption, especially given the potential that higher (perceived) risks could outweigh any expected returns. In sum, all of the above could therefore provide an explanation for the non-adoption of the improved packaging.

As a possible avenue for further research, it could be useful to extend the model to include additional important variables such as the perceived net benefit, i.e. the belief that the technology will provide benefit greater than its costs, as another potential determinant of adoption intentions (as shown in chapter 6). In specific, this could mediate the relationship between perceived usefulness and behavioral intentions (Adrian et al., 2005). Measuring the problem awareness of traders, as proposed by Subedi et al. (2009), could also give further insights on whether traders might behave differently if they assigned greater urgency to reduce postharvest losses. Similarly, in order to understand if and why traders refuse to make changes to their behavior (and therefore do not adopt new technology), the technology readiness index by Parasuraman (2000) can be considered as a further explanatory factor in the technology acceptance model. In specific, this factor could be used to explain perceived ease of use and perceived usefulness (Walczuch et al., 2007). Accordingly, by considering these changes, there is potential to extend the presented framework and thereby improve the understanding of adoption decisions across the entire supply chain.

Nonetheless, there are a number of potential limitations and, as a result, suggestions that can be used to improve future studies in this vein. First, due to the small sample size of 80 traders, it cannot necessarily be assumed that all results and statements can be generalized for all traders in Tanzania. Rather, it is more likely that the validity of these findings is broadly meaningful for this sample and within this study region. Similarly, the tomato value chain in

the Arusha region is not representative for the whole of Tanzania, given the existence of other systems in other regions. However, as mentioned in section 6.2.3, this region is one of the major tomato market in Tanzania. Aside from this, some issues also emerged during data collection. For instance, many traders evaluated the statements for one latent construct identically, e.g. PU1-PU5 all with '4' Likert scale, which could suggest that full attention was not necessarily given to the task at hand. Indeed, as might be expected, traders were still engaged in their business transactions throughout the field interviews and it seems that the loud, hectic and full market environment is not necessarily optimal for the collection of high-quality data. Of course, issues such as these are endemic to the use of field studies in the social sciences. On the other hand, another explanation for why traders may have answered identically for all the items of the aforementioned construct might be due to the similar formulation of statements. With regard to the task of field observation, limitations also include the potential (biasing) influence of both prominent respondents and the Chairpersons of the traders' association. As a result, it cannot be ruled out that the answers of the respondents were not determined by the market environment in which data collection took place. In a more positive light, the presence of these factors could also be seen to impart a greater reality to the experiment, given that individual traders are unlikely to make decisions about the adoption of new technologies in an isolated manner. Finally, it was also the case that, during data collection, the questions and statements for explanatory variables were not necessarily clear to all enumerators. That is, in spite of a training and pre-test with subsequent discussion, there remains substantial room for, e.g. improving further applications of the theories, developing new statements for latent constructs, and more thoroughly standardizing the questionnaire to suit the actual interview context (i.e. as it was the case of translating English to Swahili for this study). Through such improvements, it will be possible to ensure that such questionnaires are more broadly suitable for a range of experimental circumstances and, moreover, able to provide generalizable results regarding the adoption decisions of traders. To further advance the understanding of the factors for technology evaluation a real experimental design would be desirable especially in the light of the attitude-behavior gap.

7.7 Conclusion

For a successful implementation of new packaging or better postharvest handling techniques it is important to understand the adoption behavior of users of the techniques. Even though traders were not aware about the paper lining technology, knowledge and adoption rate are low (Kamrath et al., 2016), the factors influencing the adoption behavior give an idea for improving technologies and its introduction in the supply chain.

To the best of my knowledge, systematic and model-based research at traders' level in developing country context has been barely researched. Based on literature traders are the dominating actors – representing a special and important role – in the fresh fruit and vegetable supply chain in the developing world, future research is required for more in-depth studies in this domain. Underlying factors that contribute to rejection or adoption of technology offer insights to the psychological construct of traders (i.e. attitude, social/subjective norms and perceived behavioral control) in the tomato supply chain. Findings of the significant influence of subjective norm shows that we need to investigate the entire network as peers seem to dominate technology evaluation decisions. As a second important factor, perceived behavioral control influences significantly the technology evaluation. The factor attitude toward the packaging is positively influenced by perceived usefulness, but perceived ease of use has no significant influence on adoption behavior. This is useful for further research about tomato packaging to meet the requirements of users and avoid risks by traders. The findings of this chapter may not apply to the overall population as samples and study regions were selected purposively, but there are similar situations where traders play an important role in the food value chain in postharvest loss reduction in other developing countries. It is therefore plausible that the findings are applicable in the context of other developing countries with a similar situation as exists in Tanzania.

After presenting results of different studies on chain actors' evaluation of new food technologies, the next and final chapter provides an overview of the major outcomes of the thesis. Further, the contributions, implications as well as the limitations and future research are derived in order to bring the overall research to the context of contributing to food security by adopting new food technologies.

Part V: Discussion and conclusion

8 Discussion and conclusion

This chapter answers the research questions in the thesis (chapter 8.1), highlights the overall theoretical, methodological, and empirical contributions (chapter 8.2) as well as the implications of the study for practice and policy (chapter 8.3). It concludes the thesis by acknowledging the limitations and proposing some possible future research avenues (chapter 8.4 and chapter 8.5).

8.1 Answering the research questions

Tackling challenges in the global food system requires not only the development of new food technologies (macro-level) but also their adoption by individual chain actors (micro-level, see also Coleman's bathtub Figure 1.3) (Augustin et al., 2016; Coleman, 1990; Rogers, 1995) for successful implementation in the food system. In general, humans are usually reluctant toward new food technologies (European Commission, 2010; Lusk et al., 2014). The huge research landscape of chain actors' evaluation research is limited to the main focus on consumers and using a high diversity of different theoretical models and factors which makes comparison between and synthesizing results of studies difficult (see also Figure 1.5). Thus, the overall aim of this thesis is to enhance the understanding of food technology evaluation along the supply chain by exploring two main research questions:

Objective 1: *To develop a scientifically underpinned conceptual model for analysis of food technology evaluation.*

Objective 2: *To empirically analyze food technology evaluation at consumer and trader level with different models.*

In order to respond to the overall aim of this thesis, five overall research questions are investigated in a total of six studies while taking different perspectives as illustrated in Figure 8.1. Hereunder, I provide an answer to each of the research questions and their sub-questions, based on the results presented in the different research chapters 2 to 7.

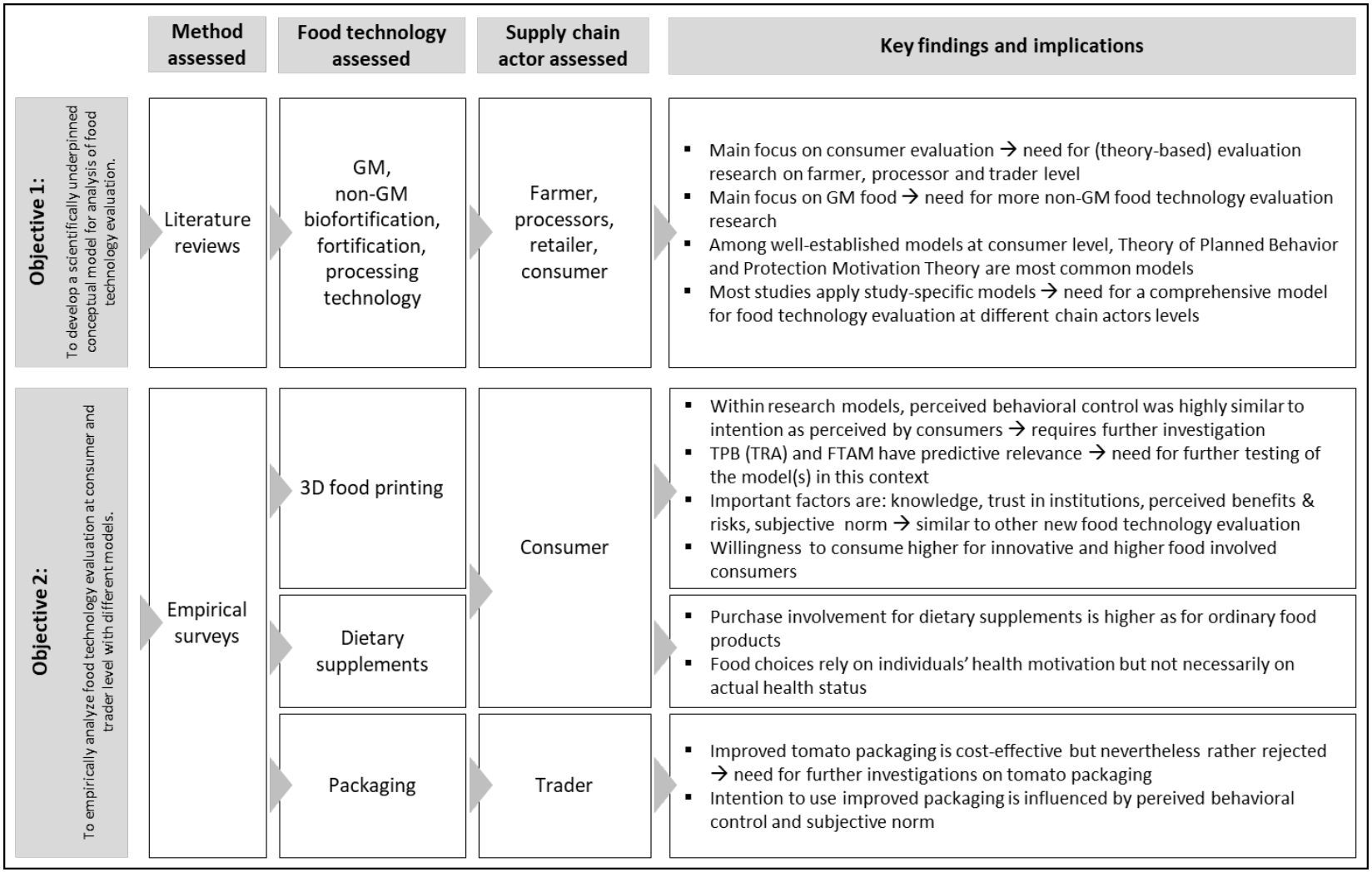

Figure 8.1: Narrative of this thesis.

Remark: TPB = Theory of Planned Behavior; TRA = Theory of Reasoned Action; FTAM = Food Technology Acceptance Model.

Source: Own illustration.

8.1.1 Objective 1: Findings of systematic reviews

For objective 1, the research questions 1 and 2 are assessed by means of a systematic literature review.

RQ 1: *Which research settings and theoretically models are used to analyze food technology evaluation?*

The aspect of theoretical models applied in the context of analyzing chain actors' evaluation of new food technologies was explored in chapter 2. This chapter provided a comprehensive review of the existing literature on new food technology evaluation studies (*N*=183). Thereby, the systematic review focused on model-based research, i.e. studies that applied theoretical models.

RQ 1.1: *What types of existing food technologies are commonly applied in model based evaluation studies?*

The findings indicate that extant research has primarily focused on GM foods compared to other food innovations. Consequently, research on non-GM biofortified, functional foods and processing technologies is limited. The tremendous focus on GM food acceptance research might be due to the general associated public controversy due to concerns on human and environmental safety (Bawa & Anilakumar, 2013; Frewer et al., 2011; Gupta et al., 2012; Uzogara, 2000). The peak in 2008 may be a possible consequence of the EU moratorium on GM crops on that time (Leibovitch, 2008). Further, although GM crops are mostly cultivated in developing countries (ISAAA, 2017), GM evaluation research is conducted in developed countries.

RQ 1.2: *What levels of the food supply chain are targeted in model based food technology evaluation studies?*

Regarding targeted food chain actors, results indicate that the main focus is on consumer evaluation of new food technologies. Only few studies could be identified at farmers' level, while evaluation research on processors/retailers is almost lacking. As such, it is not surprising that current literature reviews emphasized more on consumers' evaluation toward new food technologies (e.g. Frewer et al., 2011; Lyndhurst, 2009) as compared to other chain actors. Although consumers are a powerful actor in the food chain (Augustin et al., 2016; Floros et al., 2010), for a successful implementation strategy of promising new food technologies, the acceptance and adoption of all food chain actors is necessary (Bigliardi & Galati, 2013; Bröring, 2008; Grunert et al., 2005; Michalak & Schroeder, 2011; Rogers, 1995).

RQ 1.3: What well-established theoretical models have been used to examine food technology evaluation behavior along the supply chain?

Results of chapter 2 show that at consumer level, the Theory of Planned Behavior (TPB) and the Protection Motivation Theory are the most common models used throughout different new food technology evaluations studies. However, at farmer and processor level, no well-established models for technology acceptance research – as, for example, summarized by Hillmer (2009) – were applied, with one exceptional application of the TPB at farmers' level (Oparinde et al., 2017). Nevertheless, most studies developed study-specific models that are only used in their particular context. A study-specific model might be suited best toward the respective research objective (i.e. targeted food technology, chain actor, country, see also Figure 1.4), but makes the comparison of study results and overall evaluation of technology acceptance difficult. Therefore, chapter 2 highlights the need for a more consistent use of well-established theories for better comparison and validation of findings within as well as between food technologies and actors. However, as 85% of the studies used their own developed models, existing well-established theories might not represent (sufficiently enough) the necessities of chain actors' new food technology evaluation.

Consequently, chapter 3 identifies and compares key factors of supply chain actors' evaluation of new food technologies.

RQ 2: *What are key factors of supply chain actors' new food technology evaluation?*

Extending the database used in chapter 2 by extraction of applied factors in the studies, chapter 3 categorized the factors by use of the ecological framework (Bronfenbrenner, 1979; Story et al., 2008) and analyzed the significant relationships between factors by adapting network analysis (Brandes & Erlebach, 2005; Brinkmeier & Schank, 2005).

RQ 2.1: What are most often used descriptive and psychological factors within food technology evaluation research?

Regarding the ecological framework, more than 40% of the variables related to the physical (technology/product) or individual environment, while only 10% of the variables were categorized as macro-level. Notable, only 2% of the variables belonged to the social environmental category. For consumer studies, eight psychological factors were most often used. These were related to the physical environment (information assessment, attitude toward product/technology, perceived benefits and risks, quality perception of the product), the macro-environment (trust in institutions) and the individual (impact on health). For farmer studies, only three main psychological factors were identified, all relate to the physical level

(perceived benefits and risks, source of information). No overlap could be identified for processor studies due to limited studies included in the systematic review.

With respect to descriptive factors, consumer investigated most often influences of age, gender, education, income, presence of children/household size, and health care/status. Farmer studies focused on descriptive variables such as applied farming practices, farm size, education, age, financial benefits and also presence of children/household size.

RQ 2.2: Which factors show significant relationships to one of the indicators of food evaluation?

Evaluation was measured by using different indicators, i.e. intention/likelihood to accept, attitude to food technology, willingness to pay, acceptance, adoption and perceived benefits and risks. The above identified descriptive and psychological factors at consumer and farmer level are supported by the applied network analysis which showed significant relationships of these factors to one of the indicators of food evaluation. For example, for consumers, trust in institutions and stakeholder (e.g. government, food industry, farmers, scientists, media) increased the positive evaluation (e.g. acceptance, willingness to buy) of new food technologies (e.g. GM foods, functional food, irradiation) (among others: Gutteling et al., 2006; Sapp & Downing-Matibag, 2009; Siegrist et al., 2008a). The results serve as a first step toward a comprehensive model for food technology evaluation, especially at consumers' level because enough factors could be extracted and overlaps identified.

With regard to the overall aim of this thesis, the results of chapter 2 and 3 show that a huge diversity of applied models and factors exist, both on consumer and farmer level. Moreover, results indicate that research lacks on an overall supply chain perspective within food technology evaluation research. This yields to deepening the research on testing relevant factors for new food technology evaluation at different chain actor levels by applying empirical studies as aimed in objective 2 of this thesis.

8.1.2 Objective 2: Findings of empirical assessments

In line with the illustrated key features of empirical analysis in Figure 1.4, objective 2 was empirically investigated by three main research questions targeting (a) consumer (RQ 3 and 4 in chapters 4 and 5) and (b) trader (RQ 5 in chapters 6 and 7).

(a) Consumer studies

The underlying studies of chapter 4 and 5 targeted consumers' evaluation of new food technologies exemplified on the 3D food printer and dietary supplements, respectively. Both studies used identified factors based on chapter 2 and 3 for assessing influencing factors on consumers' willingness to consume the respective products. Data was obtained through surveys with German consumers by means of an online questionnaire (chapter 4) and computer assisted telephone interviews (CATI) (chapter 5). The analysis was based on Partial Least Squares Structural Equation Modeling (PLS-SEM).

RQ 3: *What determines consumers' evaluation toward new food technologies exemplified on 3D food printer?*

In chapter 4, building on the results of chapter 3, a Food Technology Acceptance Model (FTAM) was developed and compared to the well-known Theory of Planned Behavior (TPB). As revealed in chapter 2, TPB was the most often applied model in the context of new food technology evaluation.

RQ 3.1: What drives consumers' evaluation of 3D-printed food?

Important predictors for consumers' intention to consume 3D-printed food were knowledge, trust in institutions, perceived benefits and perceived risks as well as subjective norm. Furthermore, the analysis of consumer characteristics showed that younger participants who were male, higher educated and earn higher income were more likely to consume 3D-printed food. This also holds true for people who were more involved in food as well as those that were more innovative. Both characteristics seem to relate to a more information-seeking behavior (Mittal, 1989b; Rogers, 1995), and thus, higher involved and innovative people are more likely to build stronger mind sets about new foods and its technologies. Further, innovative people are characterized as risk takers in other studies (e.g. Dobre et al., 2009) who are likely to deal with inconvenience factors in the short-term and focus on the long-term benefits of the innovation (Faiers & Neame, 2006). Furthermore, people with a higher ecological worldview were less likely to adopt food from 3D food printers. The environmental advantages of 3D food printer seemed not to be obvious for the respondents since consumers who concern about their environmental impact of their food choices usually show more interest to try novel foods (Verbeke, 2015).

RQ 3.2: How will consumers' evaluations of 3D-printed food differ to other new food technologies?

The above presented results are in line with consumers' evaluations toward other new food technologies (see chapter 2 and 3, but also Brunner et al., 2018; Lusk et al., 2014; Ronteltap

et al., 2007; Rollin et al., 2011). For example, the relationship between knowledge and evaluation of new food technologies tends to be positive not only in the case for 3D-printed food but also for other technologies (e.g. for GM foods, functional foods and nanotechnology) as shown in several studies (among others: Annunziata et al., 2016; Kim & Kim, 2015; Lusk et al., 2004). Nevertheless, also a negative relationship could be observed in a study by Henson et al. (2008b), explained by the perceived skepticism by participants about the efficacy of a functional food to reduce a specific health risk.

RQ 3.3: *How will the model prediction of a proposed Food Technology Acceptance Model differ to a well-known theory represented by the Theory of Planned Behavior?*

The construct reliability and validity could be established after removing perceived behavioral control from both models due to a discriminant validity issue related to the constructs perceived behavioral control and intention to consume. The TRA (initially TPB) and FTAM models showed good model prediction as demonstrated by relevant R^2, f^2 and Q^2-values. Although TRA includes only two direct predictors on intention (attitude, subjective norm), the former explained 66.3% of the variance in intention to consume 3D-printed food, as compared to FTAM, which predicted 58.9% of the variance with four included factors (trust in instutions, subjective knowledge, perceived benefits, perceived risks). It was expected that FTAM would have had a higher explanatory power than TRA due to the intensive and comprehensive selection of relevant factors for food technology evaluation by consumers. The strong explanatory power of subjective norm within TRA may be explained by its relation to behavior-specific beliefs that, according to Ajzen (2012), is expected to be more proximate to intention compared to factors related to the outer environment (e.g. macro-level, Bronfenbrenner, 1979). Thus, due to the dominant role of subjective norm in TRA, it is suggested to add subjective norm to FTAM.

Furthermore, empirical consumer research focused on the involvement construct within dietary supplements evaluation research.

RQ 4: *What determines consumers' evaluation toward new food technologies exemplified on dietary supplements?*

The study in chapter 5 focused on the construct involvement which is a very important factor for understanding technology evaluation (Kröber-Riel et al., 2009). Thereby, this study explored the level of involvement of dietary supplements as compared to ordinary food

products and the factors influencing consumers' involvement as well as their purchasing decisions.

RQ 4.1: To what extent are dietary supplements subject to a higher level of involvement than 'ordinary food' products?

Results indicate that German consumers are more involved in the purchase of dietary supplements as compared to ordinary food products. Thus, consumers seem to purchase dietary supplements with a greater level of cognitive effort by intensively searching for and using existing information. The difference of purchase involvement might be explained by the different utilitarian, sign and hedonic values associated by consumers toward the products. Hence, dietary supplements are mainly characterized by their utilitarian-value 'health benefits' that requires awareness and understanding. Consequently, health related foods seem to influence consumers' involvement level positively as also supported by Bolfing (1988), Verbeke et al. (2007), and Barker et al. (2008) in the context of fiber-enriched cereals, fish or fruit vegetables, respectively.

RQ 4.2: Which factors represent potential determinants of consumer involvement in dietary supplements?

Health motivation positively influenced involvement, but the health status had no significant influence. These insights show that the purchase involvement, and in turn, healthy food choices seem to rely on individuals' health motivation rather on the actual health status. Contrary to the results in chapter 4, socio-economic factors that positively influence consumers' involvement of dietary supplements are female and older participants. Due to the physical changes of older people, they seem to be motivated higher to invest more in their health (Drichoutis et al., 2007). And women are generally characterized as being more health motivated than men (Bothmer & Fridlund, 2005; Ek, 2015). However, similar to 3D-printed food, higher incomes positively influence purchase decision involvement. Both technologies might be less affordable for low-income households. However, the level of education had no significant impact on consumers' level of involvement. The different effects of the socio-economic factors are more likely due to the fact that 3D-printed food and dietary supplements differ in their technological nature, e.g. visible vs. invisible production process. Socio-economic differences across food technologies have been explored in more detail in chapter 3, but are also underpinned by other studies, e.g. Frewer et al. (2011) or Lyndhurst (2009).

With regard to the overall aim of this thesis, both studies (chapter 4 and 5) focused consumer perspectives on food technology evaluation. They introduced a general Food Technology Evaluation Model as well as analyzed the concept of involvement in detail.

(b) Trader studies

The implementation of new technologies in the food system is not only dependent on consumers, but also on a positive evaluation of other chain actors. Therefore, further investigation of the evaluation of new food technologies was undertaken at traders' level.

RQ 5: *What determines traders' evaluation toward new food technologies exemplified on an improved tomato packaging?*

Chapter 6 presents a field-experiment combined with a cost-benefit analysis to assess the effectiveness of an improved tomato packaging (lining material for standard wooden crates), conducted in Tanzania. Further, this chapter investigates the correlation between traders' perceived net benefits and willingness to use wooden crates with paper lining based on a face-to-face survey with tomato traders. As the willingness to use improved packaging might not only depend on monetary benefits but also on other variables, chapter 7 expands the research on traders' evaluation of improved packaging and examines psychological factors by using the method of PLS-SEM.

RQ 5.1: *What is the effectiveness of introducing different lining material to enhance tomato packaging?*

The results of the cost-benefit analysis indicate that paper lining for standard wooden crate is profitable, especially in the off-season (i.e. low season, high prices). However, using Hessian cloth lining material is only profitable in the long run. These results are similar to other packaging interventions (Kitinoja et al., 2011).

RQ 5.2: *To what extent perceive traders net benefit of improved tomato packaging as determinant for willingness to adopt the improved tomato packaging?*

The results indicate that although paper lining for standard wooden crate is profitable, willingness to use rate by traders was low for varied reasons, but increased for traders who believed that the alternative packaging can increase profits. Major reasons for rejecting were concerns related to the practicability and applicability during the rainy season, lack of awareness, knowledge, as well as evidence of any success for its use, the accessibility to lining material, and increased handling costs. Furthermore, traders mentioned problems regarding the uncertainty about retailers' willingness to buy tomatoes in standard wooden

crates with lining materials because tomatoes cannot be visually inspected. Similar concerns related to postharvest technologies are also stated within studies by Kitinoja et al. (2010) and Kitinoja (2013). Thus, the diffusion of improved tomato packaging in Tanzania also depends on the understanding and communication between supply chain actors. This is also especially evident in stated recommendations that small scale farmers in rural areas should be guaranteed better market access in order to reduce postharvest losses (FAO, 2013b; Kader, 2005; Kitinoja et al., 2011). This could be achieved through better cooperation with traders.

RQ 5.3: What are the main psychological factors driving traders' evaluation of a new type of wooden crate with lining?

Based on the combined model of the Theory of Planned Behavior and the Technology Acceptance Model (TAM), results concluded that the perceived behavioral control and subjective norm were important factors explaining respondents' behavioral intention. Subjective norm was also found to be a significant factor for food technology evaluation at consumer level (chapter 4). Nevertheless, consumers assessed perceived behavioral control highly similar to intention, thus, perceived behavioral control had to be removed and an effect could not be analyzed. It could be argued, that perceived behavioral control might be more interesting for upstream actors in the food chain than for consumers, e.g. for farmers (Oparinde et al., 2017).

Attitude, though found not to be a significant determining factor, however, was significantly influenced by perceived usefulness and perceived ease of use. These results are supported by an extensive literature analysis on interventions that have been attempted to mitigate postharvest losses (Affognon et al., 2015).

RQ 5.4: What are main explanatory factors that affect the psychological constructs of the evaluation of improved packaging?

Explanatory variables such as the characteristics of traders (e.g. age, gender), type of packaging, trading network, trading patterns, profit and transportation issues lacked significant moderating results to explain group segmentation. This might be explained by the small sample size in this study. Nevertheless, at other supply side levels, e.g. farmers, the importance of socio-economic factors (e.g. education) for evaulation of new food technologies is broadly established by various studies (Abass et al., 2014; Affognon et al., 2015; Aidoo et al., 2014; Ali, 2012; Feder et al., 1985; Tenge et al., 2004).

With regard to the overall aim of this thesis, chapter 6 and 7 expands the focus beyond consumers to the supply side of the food chain. Both studies identified main factors influencing

food technology evaluation at trader level. In a further step, outcomes of all studies have to be discussed regarding differences of relevant factors regarding new food technology evaluation along the supply chain.

8.1.3 Research findings in relation to the thesis' aim

Overall, the four empirical chapters 4, 5, 6 and 7 encompass empirical research that tests and identifies relevant factors in new food technology evaluation research at consumers' and traders' level (an overview is provided in Figure 1.5) The factors which are used in those studies are based on results of chapters 2 and 3. Overall, according to the ecological framework by Bronfenbrenner (1979), technology evaluation is indeed influenced by different levels, i.e. intrapersonal factors (e.g. attitudes), interpersonal environment (e.g. subjective norm), physical environment (e.g. perceived benefits of a food technology) as well as macro-level environments (e.g. trust in institutions). All levels should be considered in behavioral research and be addressed for most effective interventions in changing behavior. A single-level intervention is unlikely to have powerful or sustained effects (Sallis et al., 2008). Thereby, for analyzing new food technology evaluation, relevant factors are contingent upon:

- the chain actor targeted (consumer vs. trader)
- type of technology,
- and research setting.

While respect to the *chain actor* targeted, it seems that evaluation research at consumer level merely investigates the willingness to pay for a specific product as shown in the literature review (chapter 2 and 3). However, at trader level the perceived net benefits are a relevant monetary measurement (chapter 6). With regard to *technology*, health related factors are of interest when dealing with dietary supplements, while for packaging technology more practical factors like perceived usefulness and perceived ease of use are applied. With respect to the *research setting*, cultural differences need be taken into account as some countries are very homogeneous whereas others are very heterogeneous regarding food behavior and attitudes (Askegaard & Madsen, 1998; Pieniak et al., 2009; Prescott et al., 2002). This impacts the choice of variables (Askegaard & Madsen, 1998) as well as its measurements (Bruns & Grunert, 1995). Further, technology and country are related to each other. For instance, evaluation research of processing technologies such as HPP is dominating in developed countries but are not (or less) investigated in developing countries (as shown in chapter 2 and 3). According to Jermann et al. (2015), this can be explained not only by the costs, i.e. representing barriers to investment, but also on the national popularity of a technology, i.e.

cultural influences of a country. Both factors seem to influence the implementation of a specific technology.

However, the underlying results of this thesis also show that some factors are relevant across targeted chain actors, technologies and research settings. For instance, subjective norm was a strong predictor for the intention to consume 3D-printed food for German consumers but also for the willingness to use improved packaging by Tanzanian tomato traders. Furthermore, subjective norm was a relevant factor in several other studies in food evaluation research (chapter 2). For example, subjective norm was a significant positive predictor for adopting GM crops by farmers in Nigeria (Oparinde et al., 2017), and GM foods by consumers in Taiwan, New Zealand, Iran, South Korea, USA (Chen, 2008; Cook et al., 2002; Ghoochani et al., 2017; Kim et al., 2014; Lu & Gursoy, 2016), as well as for consumers' evaluation of functional food in Taiwan (Tsai et al., 2010), and nanotechnology in New Zealand (Cook & Fairweather, 2007). But subjective norm was also shown to be insignificant in several cases, for example, for consumers evaluation of functional food in Taiwan, Australia (Chen, 2017; Patch et al., 2005), of GM foods in UK (Spence & Townsend, 2006) but also of non-GM biofortification in Kenya (Talsma et al., 2013). Mentioned reasons behind were recent food safety scandals related to the targeted technology in the country which might have fostered strong opinions among the individuals, and thus, do not rely on opinions of important others around them (Chen, 2017). Another stated reason was, that staple foods that are generally consumed by a population are well accepted in the community and therefore normative beliefs regarding consumption are low (Talsma et al., 2013). In general, a study by Armitage & Conner (2001) indicated that subjective norms are often the weakest predictor for intention which is contrary to the results of 3D food printer (chapter 4). Notably, subjective norms as part of the social norms have emerged culturally over many years (Chudek & Henrich, 2011), and thus, differ between contexts, as also shown in the two empirical analysis investigating subjective norm in different contexts within this thesis.

In conclusion, comprehensive evaluation research is of high interest for understanding chain actors' reactions toward new food technologies in the food sector, and in turn, is a basic element for developing successful diffusion strategies of technologies in the food system.

8.2 Scientific contributions of the thesis

Chapter 1 gives a solid account of theoretical linkages between new food technologies in the food system (macro-level achievements) and its necessary behavioral intention by individuals (micro-level) to adopt these technologies, i.e. microfoundation. This thesis contributes to the

microfoundation approach by replicating, extending, as well as developing innovative theoretical, methodological and empirical approaches for the analysis of food technology evaluation at the micro-level. As shown in Figure 8.2, those approaches serve as moderator variables for a better understanding of new food technology evaluation by all relevant supply chain actors. Further, Table 8.1 categorized the theoretical, methodological and empirical contributions to theory by their level of contribution. Overall, the contributions are underpinned by findings in the research chapters 2 to 7 and are elaborated below.

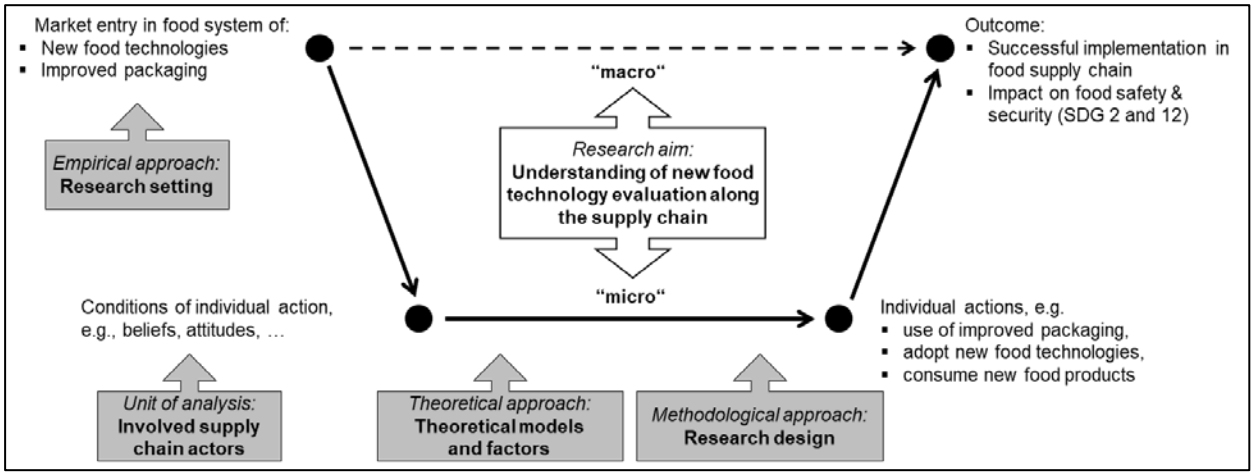

Figure 8.2: Moderator variables for Coleman's Bathtub.

Source: Adapted and extended from Coleman (1990).

Table 8.1: Scientific contributions of this thesis.

Type of contribution	Level of contribution		
	Replication	**Extension**	**Innovation**
Theoretical	▪ Adaptation of the evaluation concept ▪ Adapting the microfoundation approach ▪ Adaptation of the TPB ▪ Identifying well-established theoretical models	▪ Extending the scope with respect to supply chain actors, new food technologies ▪ Extending the TPB to a combined model of TPB + TAM ▪ Extending the measurement of perceived benefits and risk to 5 dimensions	▪ Systematically analyzing and categorizing of influencing factors ▪ Development of a new Food Technology Acceptance Model
Methodological	▪ Investigating different sampling procedures and adaptation of techniques to enhance data quality ▪ Adaptation of PLS-SEM and PLS-MGA in data analysis	▪ Adapting three approaches to extend the analysis of literature by means of a systematic literature review - Inductive category development - Ecological framework - Network analysis	▪ Developing and applying a measurement for objective knowledge about 3D food printer
Empirical	▪ Adaptation of influencing factors on evaluation	▪ Enhances empirical understanding of consumers' and traders' evaluation	▪ Application of the proposed FTAM ▪ Comparison of the FTAM to the TPB

Remark: All contributions are on the background of new food technology evaluation research. TPB = Theory of Planned Behavior. TAM = Technology Acceptance Model. FTAM = Food Technology Acceptance Model.

Source: Own illustration.

8.2.1 Theoretical contributions

Systematic literature reviews – While investigating the individual level, this thesis provides insights to academic scientists to better understand influencing factors for chain actors' evaluation of new food technologies. Most of the developments in the food system are purely technology push, which may neglect some influencing factors related to adoption behavior (e.g. perceived usefulness). Chapter 2 and 3 identify and present research gaps by providing a systematic literature review (Petticrew & Roberts, 2006) including 183 studies, which are addressed within this thesis. Thus, this thesis contributes to the theoretical understanding of technology evaluation by (1) extending the focus beyond consumers to other food supply chain actors, (2) targeting a wider range of new food technologies, and (3) examining the use of well-established explanatory models as well as (4) identifying key factors. For the latter, this thesis contributes, in addition, to the multi-level understanding of factors relevant for food technology evaluation by adapting the ecological framework (Bronfenbrenner, 1979; Story et al., 2008). Overall, results show that factors related the physical environment (e.g. attitude toward a technology) and individual factors (e.g. impact on health, education) are primarily used for analyzing the food technology evaluation of individuals.

Consumer studies – Results from chapter 3 contribute toward the understanding of theory-based research while developing a theoretical model including main factors influencing new food technology evaluation at consumer level. In chapter 4, the theoretical linkages (i.e. research hypotheses) of this proposed Food Technology Acceptance Model (FTAM) are developed with their accompanying rationale. An overall explanatory model suitable for the respective chain actor would benefit a more consistent and comparable research. With respect to new food technology evaluation, comparison of research results based on FTAM could simplify some steps of the research process (e.g. cases could be drawn from a predetermined set, i.e. choice and measurement of factors). Comparison can also lead to identify explanations for existing contingency while comparing observed characteristics of the individuals in different research settings as well as to a greater insight for possible explanations in terms of national likeness and unlikeness of food technologies (Hantrais, 1995). Further, comparison benefits the understanding of historical societal technological evaluation by comparing differences of technology evaluation between cases over time. Moreover, comparison has the chance to bring research results from different backgrounds and disciplines together (Ragin, 2014) in order to enhance the overall food technology evaluation understanding.

Although the use of established theories might lead to a 'path-dependent development' (Mahoney, 2000)[20], which benefits the comparison of research results along with its above mentioned advantages, 'path dependence' is followed by respective limitations. For example, with respect to new food technology evaluation, a heavy focus of one theory (e.g. TPB) would imply the risk that context-specific factors (e.g. trust in information and knowledge) are ruled out and upcoming reasons for behavioral technology adoption are neglected. The development of the proposed FTAM is based on 30 years of quantitative research. Hence, the different paths in food technology evaluation research are summarized, thus, FTAM research could also become path-dependent (similar to TPB). In order to break the path, qualitative research in this domain, which is of exploratory nature and identifies context-specific factors, should support the quantitative research. This was observed in the systematic literature review in chapter 3, i.e. included qualitative studies supported the developed FTAM. With regard to the adaptation of FTAM, this model should not be considered as a static model, but rather as a basic model allowing different, but comparable paths (similar to the Technology Acceptance Model by Davis, 1986, which has undergone various extensions after its development, e.g. see Venkatesh et al., 2003; Venkatesh & Thong, 2012).

Furthermore, chapter 4 enhances the knowledge and measurement of perceived benefits and risks in the domain of new food technology evaluation by introducing a measurement of these constructs based on different dimensions (i.e. convenience, naturalness, economic, environment, health). Accordingly, this thesis provides an evaluation of the entire range of benefit and risk dimensions of consumer evaluations, rather than only focusing on a narrower perspective of the benefit and risk aspects involved. This measurement extends the research by Butkowski et al. (2017), who identified relevant risk dimensions for genetic engineering food technologies.

Trader studies – With respect to food technology evaluation research from the supply side perspective, chapter 6 and 7 add to the theoretical knowledge by providing insights to the theoretical analysis at traders' level, by extending the TPB to a combined model of TAM and TPB. Therefore, this thesis contributes to the theoretical evaluation research in developing countries because model-based research at traders' level in developing countries has been barely researched. The TAM can be included in TPB because both theories are extensions of the TRA (Mathieson, 1991). The applicability of the framework found also evidence in the

[20] According to Mahoney (2000), path dependence can be characterized as "specifically those historical sequences in which contingent events set into motion institutional patterns or event chains that have deterministic properties" (p.507). Transferred to the case of analyzing chain actors' evaluation of new food technologies, path dependence explains how the set of decisions one faces for a specific circumstance, e.g. choice of the theoretical framework, is limited by the decisions one or other researcher has made in the past or by the past research experiences, even though past circumstances may no longer be relevant.

context of technology evaluation by farmers (Adnan et al., 2017) in addition to the original context of information systems adoption (Aboelmaged, 2010; Nasri & Charfeddine, 2012).

Overall, this thesis contributes to the theoretical understanding of new food technology evaluation by i) identifying well-established theoretical models feasible in the context of new food technology evaluation research, ii) systematically analyzing and categorizing as well as providing a comprehensive overview of influencing factors (see Figure 1.5), and iii) developing a proposed Food Technology Acceptance Model for consumer food technology evaluation research.

8.2.2 Methodological contributions

This thesis utilized a mix of methods in a unique manner to contribute new insights in the context of food technologies. Generally, the methodological contributions of this thesis refer to different data collection and data analysis methods that are applied in novel contexts such as targeted population (in terms of chain actor level and country) and food technology (e.g. GM foods, 3D food printer, dietary supplements and food packaging). This could serve as a sample design for other studies.

Systematic literature reviews – Notably, chapter 3 adapted several methods for identifying key factors in chain actors' new food technology evaluation research. First, after assessing a systematic literature review following Petticrew & Roberts (2006) the extracted factors were grouped into broader variables by adapting the procedure of inductive category development that is usually used for analyzing text data (Hsieh & Shannon, 2005; Mayring, 2000; Schilling, 2006). This approach is a successful strategy to systematically and transparently reduce the amount of data. Second, in order to organize the extracted and synthesized factors, the theory of the multi-level ecological framework (Sallis et al., 2008; Story et al., 2008) was used. Thus, this research contributes to methodological approaches by extending the applicability of the ecological framework for systematically differentiating factors from the individual to the macro-level environment in the context of new food technology evaluation. Third, for the analysis of significant relationships between key factors, the approach of network analysis was utilized. Originally, network maps are used for social networks, information networks, and transportation networks (Cherven, 2013). However, chapter 3 shows that network analysis is also a suitable tool for analyzing and visualizing relationships between factors influencing food technology evaluation and, thus, can be a valuable tool for other studies about individuals' behavior in specific contexts.

Empirical research – This thesis investigates different sampling procedures to collect data and adapts recommended techniques to enhance data quality in various settings. Thus, it contributes to the methodological understanding for conducting research in the context of chain actors' new food technology evaluation.

For data analysis, this thesis applies PLS-SEM using Smart PLS 3 of different topics and in various settings. Overall, this research contributes to researchers' enhanced understanding of how to use this technique and reinforces its use in the context of new food technology evaluation. Furthermore, among new food technology evaluation studies, few studies have made use of a multi-group analysis within PLS-SEM (PLS-MGA) to identify significant different path coefficients across two or more groups of respondents, i.e. moderating effects of socio-economic characteristics of the individual (e.g. Rodríguez-Entrena et al., 2013; Rodríguez-Entrena & Salazar-Ordóñez, 2013). Nevertheless, multi-group analysis was applied in several studies using the CB-SEM approach (Costa-Font & Gil, 2009; Costa-Font & Gil, 2012; Kim et al., 2014; Klerck & Sweeney, 2007; Siegrist, 2000). In this regard, the main advantage of multi-group analysis, as presented in chapter 4, is the resulting potential to explore which relationship is mainly moderated by specific respondents' characteristics. Hence, interventions and communication strategies can be designed more precisely for specific consumer segments.

Regarding measurement of constructs, this thesis is among the first that develops and presents 10 true-false questions to measure objective knowledge for 3D-printed food (chapter 4). Although these questions were developed based on extended literature, further investigations on their performance are needed, e.g. randomization of several items with different samples (DeVellis, 2016). Moreover, true-false questions tend to bias the assessment of objective knowledge due to a greater probability of answering an item correctly (i.e. 50%) than responding to, for example, multiple choice items (e.g. 25%, if there are 4 response options) (Burton, 2004; Zhang & Liu, 2015). However, both of these objective knowledge measures are likely to facilitate guessing of the correct answers due to close-ended response formats. Contrarily, unstructured, open-ended response formats could be used which allow respondents to provide, in their own words, answers to questions (Carlson et al., 2009). However, open-ended responses need to be extensively coded by researchers for assessing the knowledge level which evokes potential bias (Reja et al., 2003). Further, respondents may not be motivated enough to complete a whole questionnaire, thus, open-ended questions trigger larger item non-response (Evans & Mathur, 2018; Vannette, 2017).

In conclusion, this thesis contributes to research methodologies by i) adapting several approaches for analyzing literature by means of a systematic review, e.g. network analysis of factors, ii) investigating different sampling procedures in different settings with several techniques to enhance data quality, and iii) adapting PLS-SEM and PLS-MGA in the data analysis for new food technology evaluation, as well as iv) developing an objective measure for technology knowledge with regard to 3D food printer.

8.2.3 Empirical contributions

The empirical contributions of this thesis are related to applications of different established behavioral theories and socio-psychological factors to understand chain actors' reactions toward new technologies in the food system. Specifically, the research focused on consumers (chapter 4 and 5) and traders (chapter 6 and 7).

Systematic literature reviews – The results of the systematic literature reviews contribute to the assessment of empirical research of chain actors' new food technology evaluation by identifying research gaps in this research domain, i.e. imbalances due to research that dominates GM food evaluation by consumers in developed countries. These gaps needs to be empirically assessed for achieving a more comprehensive understanding of chain actors' new food technology evaluation.

Consumer studies – This thesis builds upon existing empirical research to enhance the empirical understanding of consumers' food technology evaluation in different contexts. Hence, the empirical research at consumer level in the thesis focused on German consumers evaluating 3D-printed food and dietary supplements by investigating influencing factors and expanding the empirical research from chapters 2 and 3.

Regarding the factors analyzed, this thesis contributes to a deeper understanding of the involvement construct, i.e. different measurement scales, and its influencing factors (chapter 5). Involvement is an important factor for purchase (Kröber-Riel et al., 2009; Teng & Lu, 2016) as involved people are likely to seek more information (Mittal, 1989b; Teng & Lu, 2016), and thus, can be better reached with information campaigns to enhance technology adoption. Ultimately, it is of interest to understand what triggers involvement in order to make people involved by addressing the respective determinants. Therefore, this thesis contributes to the understanding of influencing factors for involvement in the context of health-enhancing food technologies.

Notably, this thesis presents the first step in the direction of a Food Technology Acceptance Model (FTAM) by empirically testing the model using the case of 3D-printed food while

comparing it to the Theory of Planned Behavior (TPB). The proposed FTAM is contingent upon the empirical setting food, whereas TPB is a rather parsimonious but general behavioral model which is widely used through different disciplines (Armitage & Conner, 2001). The FTAM can contribute to a better comparison of results across various food technologies. Hence, it might be a tool to assess the market readiness of a technology but could also help to build technologically specific communications since technologies differ in their perceived benefits and risks (Frewer et al., 2016) in order to make the acceptance of that technology more likely.

Trader studies – This thesis especially contributes to the empirical understanding of new food technology evaluation by extending the focus to the supply side of the food chain, represented by traders. While applying the combined model of TAM and TPB, this thesis is one of the earliest works to test the theoretical linkages between the included constructs in the context of traders in a developing country. Hence, the results provide relevant factors that influence adoption behavior of traders in the context of tomato production sector in relevant developing countries.

Overall, this research enhances empirical understanding of two aspects: i) consumers' intention to consume food derived from new food technologies while being the first applying the proposed Food Technology Evaluation Model and ii) extending the focus of food technology evaluation to the supply side while analyzing traders' intention toward new food technology.

8.3 Implications for practice and policy

This thesis is grounded in current global development debates concerning linkages between future food needs and new food technologies. With an appeal to the global development agenda to achieve food security, specifically intertwined with targets of SDG 2 ('Zero hunger') and 12 ('Responsible consumption and production'), it is important to reflect upon possible implications this research has for food industry and policymakers as implementers of new technologies in the food system. These are elucidated in the following sub-sections.

8.3.1 Implications for food industry

The presented dynamics in the food system (chapter 1) raises several challenges posed to the food industry. In this context, the digital revolution is likely to provide new opportunities in food processing automation (e.g. 3D food printer) and to solve ethical and safety aspects of food production (Augustin et al., 2016). Based on the microfoundation approach, innovations

in the food system depend on the positive evaluation by the involved chain actors. In this regard, the thesis identifies the following major implications for food processing industry players who are in the centre position between farmers, and consumers.

Farmers – This thesis systematically identified factors to explain how farmers build their opinion about new food technologies. The food industry could benefit from this knowledge by establishing successful collaborations with farmers in order to develop adoption strategies for new food technologies. For instance, with respect to the aim to offer more healthy and sustainable products, the collaboration could promote the adoption of biofortifying crops. This thesis implies that farmers evaluate new food technologies especially based on the perceived benefits and risks of a new food technology along with financial benefits. Therefore, while building collaborations, those factors should be considered and properly addressed in detail by providing necessary information. In addition, the food industry should concentrate on bigger farms, as farm size was a key factor for implementing new food technologies.

Consumer – The proposed Food Technology Acceptance Model (FTAM) may be applied in all the emerging fields of novel food technologies in order to assess the overall evaluation of a technology and to avoid upfront rejection. Food industries could further benefit from this model with respect to evaluation of the current food technology adoption status of different technologies.

From a marketing point of view, a successful implementation of new food technologies relies on knowing the needs and potential reactions of the population or specific target groups (Augustin et al., 2016; Musgrove & Fox-Rushby, 2006; Pieniak et al., 2009). This thesis implies not only *how* to address consumers but also *who* should be addressed. For the *how*, the thesis specifically highlights the importance of trust in institutions, the level of knowledge, perceived benefit and risks on how consumers decide for their food (technology) preference. These identified factors require special attention by the food industry for successfully developing appropriate product and technology specific communication and positioning strategies. For instance, consumer perceive some food technologies as rather beneficial (e.g. functional food) compared to perceived risky technologies (e.g. GM foods) (see section 3.3.3, but also Frewer et al., 2016). For both, labeling are effective communication tools between industry and consumers (Messer et al., 2017), e.g. ‘health claims’. Moreover, trust in food industry could be enhanced by more transparency in the food system (Hofstede, 2007), e.g. the development of blockchains can have a tremendous impact on the effectiveness of traceability throughout the food supply chain (Mao et al., 2018).

Hereby, with respect to providing information, this thesis showed that higher involved consumers look more intensively for information. According to Mittal (1989b), this is especially

the case for products with utilitarian values which is underlined by the targeted dietary supplements in chapter 5. To investigate the understanding of involvement by consumers is especially interesting for food industries, as involvement is an indicator for the time dedicated by consumers to read and understand the packaging information (Silayoi & Speece, 2004), e.g. labeling and nutritional information. Therefore, this thesis implies that notably the health motivation instead of the actual health status is relevant for consumers' purchasing involvement, with respect to health-enhancing food products (i.e. dietary supplements).

With regard to *who* should be addressed, especially for 3D-printed food marketing, the results of the multi group analysis within the proposed FTAM imply specific consumer characteristics moderating the effect of influencing factors. In this regard, men were more willing to consume 3D-printed food than women and could be addressed first. In order to reach women, food industry should build on the trust in food industry by female consumers as it will affect the perceived benefits of new food technologies positively (more than men), and in turn the probability of buying the new product. Women still play the role of nurturer and care provider at home in the family, and thus, may be more sensitive to food related topics (BMFSFJ, 2016). Further, results showed that consumer with higher ecological worldview are less likely to consume 3D-printed food, which implies that the environmental benefits might not be obvious for consumers. Thus, marketing strategies should consider information and evidence for the environmental advantages of 3D food printer. In addition, results imply that innovative individuals, also characterized as risk takers (Dobre et al., 2009), are more likely to consume 3D-printed food while evaluating perceived benefits higher and perceived risks lower as less innovative people. Food companies could benefit from this evaluation behavior of innovative people as they are likely to try out new technologies, and thus, could serve as catalysts for the implementation of 3D food printer in the society. Other descriptive characteristics of consumers who are likely to accept 3D-printed food are young age, being male, academical educated and having higher income.

Moreover, results of this thesis highlight the importance of social influences on consumers' food related decisions. Thus, companies could benefit by identifying not only early adopters but also peers within social groups who are highly influencing their social surrounding, although interpersonal influences are highly diverse in different settings (Valente, 1996), and requires precise understanding of the population.

8.3.2 Implications for policymakers

This research provides different building blocks that need to be addressed by governmental strategies so as to achieve a successful future food strategy with respect to reach SDG 2 and

12. As such, governmental interventions would benefit by collaborating with and involving all relevant chain actors. Hence, policymakers serve as a mediator between scientific innovations and both the supply side (e.g. farmer, trader or processing industry), and the demand side (i.e. consumers). Therefore, to understand key factors driving food technology evaluation by relevant chain actors is of high interest for policymakers in order to successfully enhance the implementation of new food technologies. Interventions and regulations that are in line with industries and consumers may help policymakers to develop key strategies to safely and sustainably attend food and nutrition demands of the future, e.g. appearance of the food, product positioning, and ensuring food safety. In more detail, implications of this thesis of how factors can be used for policymakers are elaborated below, respectively for different supply chain actors.

Food industry – The choice of the right policy instrument[21] to effectively influence the targeted behavior, e.g. adoption of new food technologies by food industry, is important (Kaine et al., 2017). Hence, policymakers require not only scientific and technical information of the food technology (Donatti et al., 2017), but also a comprehensive understanding of factors determining farmers' or processors' behavior (Kaine et al., 2017) to deliberately and systematically choose policy instruments. Against this background, this thesis implies few factors that are important determinants for farmers' evaluation of new food technologies, i.e. perceived benefits and risks as well as financial benefits. Nevertheless, a more detailed understanding of individuals at the supply side of the food chain is needed.

Trader – With respect to developing countries, results of this thesis imply that the social network and distribution of power in the food supply chain as well as market structures are responsible for the successful implementation of postharvest interventions. For instance, power distribution between actors may differ across countries, e.g. in Ghana it is the female 'market queens' who generally have the most power in the tomato supply chain (Lyon, 2003) compared to the male tomato trader in Tanzania (Koenig et al., 2008). The identification of the power distribution in food chains enables to identify key actors with high influence on the success of new technology implementation who should be addressed for implementation strategies. This also bears the potential to empower vulnerable actors (Mwagike & Mdoe, 2015).

Further, the thesis provides evidence that trader associations act as peers who seem to dominate technology adoption decisions. Thus, policymakers in developing countries would benefit from collaborating with trader associations which have influencing power on traders'

[21] Some instruments, such as regulations, are intended to compel changes in behavior. Others, like incentives, are intended to induce voluntary changes in behavior.

knowledge and opinion for developing strategies to reduce postharvest losses during packaging, transportation, and selling. In addition, results indicate that perceived risks hinder a successful implementation, which requires investment by respective actors. Risks of investments could be addressed by supporting trader associations in order to organize a collaborative investment pool, which enables the division of costs (and risks) by many traders, enhancing the innovation diffusion. For policymakers, this implies to provide appropriate training but also financing tools (e.g. credit possibilities), which has been proved to be effective for successful technology implementation (Batra & Mahmood, 2003; Hodges et al., 2011).

Consumer – This thesis points out that new food technologies are necessary to tackle challenges in the global food system. Therefore, as stated by Musgrove & Fox-Rushby (2006, p.227), "the effectiveness of an intervention [e.g. new food technologies] and, therefore, the degree to which it deserves priority depend on how far it is culturally appropriate or acceptable for the population it is intended to benefit". This research implies that the evaluation of new technologies with respect to consumers is especially depending on the trust in institutions which involves governmental institutions, research institutions as well as regarding the food industry. Consumer organization like the European Consumer Organization (BEUC)[22] – in their role of giving consumers a voice in politics (Kleis, 2019) – can support the communication between the institutions and consumers, and thus, contribute to more trust in food topics. Therefore, consumer organization could provide objective information about benefits and risks of products from industries to consumers, which may enhance consumers' trust in institutions (Khedkar et al., 2017). For instance, research elucidated that objective information about GM foods increased its acceptance (Klerck & Sweeney, 2007; Lusk et al., 2004). Overall, this implies need for cooperation among government, scientific institutions, and the food industry to foster effective communication strategies that increase consumers' objective knowledge, which in turn increases their perception of benefits and reduce their risk perceptions, and encourage consumer acceptance of new food technologies (chapter 3 and 4). Hence, consumer organizations are important intermediaries who could disseminate relevant knowledge by organizing information campaigns. In this respect, the proposed FTAM presents a basis to compare different technologies, and thus, to design respective communication strategies based on the evaluation results. Hence, the model offers the opportunity to develop multi-level interventions on consumers' evaluation of new food technologies which are more effective, powerful and sustainable than single-level interventions (Sallis et al., 2008). For example, the comparison of consumers' evaluation toward new food technologies by making

[22] The European Consumer Organization (BEUC) can be considered as a secondary policymaker as it witnesses developments in the EU's consumer policy and lobbying landscape Kleis (2019).

use of the proposed FTAM, could foster interdisciplinary and European-wide collaborations in social sciences. The upcoming results would benefit the European Commission to establish European-wide large-scale interventions, e.g. subsidies for healthy food, 'health-claim' labeling or at workplace settings (European Commission, 2018a).

To sum up, it can be said that in order to achieve successful adoption of novel technologies in the food system, there seems to be a need for establishing an implementation framework which fosters collaborations between academic scientists, consumers, industries as well as policymakers. Representative from all domains could invest efforts in addressing the conception of successful strategies to implement promising new food technologies in the food system. Such a framework requires understanding of influencing factors on new food technology evaluation by involved chain actors (Figure 8.3). This benefits the process of developing interventions with relevant chain actors, and thus, successfully developing strategies and policies aimed at facilitating new technologies in the food system which brings more valuable improvements for the society.

8.4 Limitations of the thesis and directions for future research

An overview of important general limitations which should be considered for future research to advance knowledge developed in this thesis are discussed in the following paragraphs.

(a) Theoretical approaches

First, based on the microfoundation approach, this thesis assumes that the micro-factors (e.g. values, beliefs of individuals) trigger a sustainable change process for future food security more than the macro-factors (e.g. regulatory, market developments). However, investigating the macro-perspective could provide additional insights into the impact of new food technologies on food supply. In this context, the assessment of how likely the adoption of a technology by respective chain actors at the micro-level is (e.g. by applying the proposed Food Technology Acceptance Model), could serve as an input variable for the macro analysis.

Second, as research becomes more complex with the increasing combination of different theories and technologies, the use of empirically grounded tools for science management is recommended. In this regard, this research applied two well-known theoretical models, i.e. Theory of Planned Behavior and Technology Acceptance Model. According to chapter 2, several other theories exist which could be examined in future research. Hence, research should benefit from the appropriate use of terminology related to food technology evaluation.

This could be achieved by harmonizing definitions and measurement approaches (Hess et al., 2016; Mogendi et al., 2016b) related to food technology. In addition, academic scientists should make use of standardized approaches in future studies (Bredahl et al., 1998; Lusk et al., 2014) for assisting the comparison between studies. In this regard, the thesis is the first that tested the proposed Food Technology Acceptance Model (FTAM) developed based on results of chapter 2 and 3, but requires further evidence. The introduced scale and measurement of perceived benefits and risks of new food technologies with regard to the different dimensions also needs further investigation.

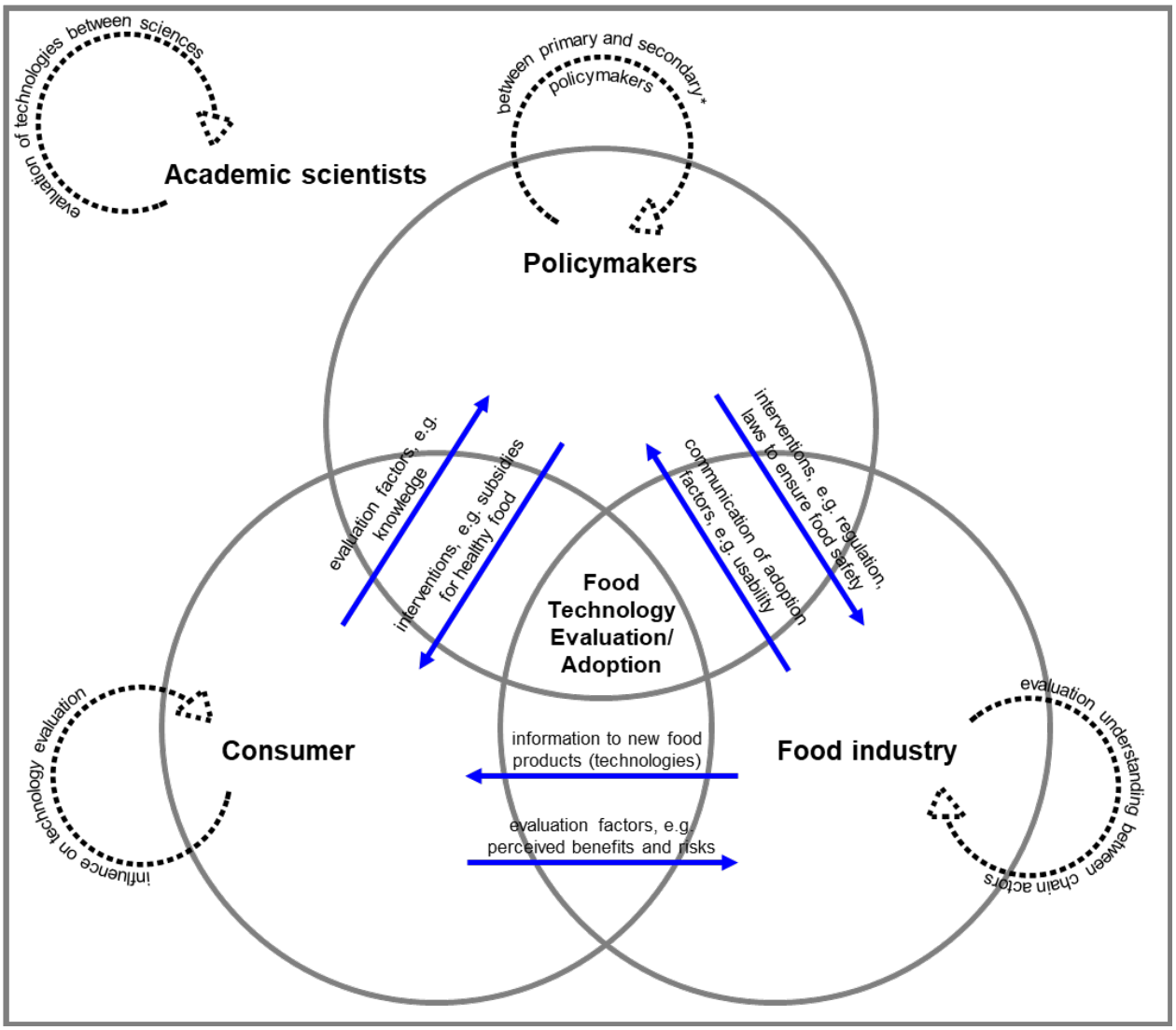

Figure 8.3: Overall relationships of food technology evaluation between stakeholders.

Remarks: * Primary = governmental policymakers, secondary = consumer organizations.

Source: Own illustration.

Third, with respect to investigated factors, this research highlights the influence of important others in the decision making of food innovations by chain actors. However, the measurement, following Ajzen (1991), is rather general, e.g. 'the people in my life whose opinions I value would approve that I consume' the innovative food or use innovative technologies (see Appendix G and Table 7.3), neglecting who are the important person in someone's decision-making process in the food technology evaluation context. Hence, influencing others can be distinguished between weak (e.g. people you meet at a conference, or on a cruise) and strong (e.g. close friends and family) ties (Granovetter, 1977). According to Granovetter (1977), not the strong ties but rather the weak ties – those who bring new ideas to your community – are important people for innovation diffusion. In this regard, it would be of interest to analyze who is primarily influencing food evaluation by the individual.

(b) Methodological approaches

First, the systematic review presented in this thesis optimizes the validity of review outcomes through procedural objectivity (i.e. adherence to an auditable protocol). However, it does not remove the subjectivity of the process, for example, the formulation of the search syntax, the screening and extraction process as well as the analysis and interpretation of the paper. Future studies can extend and improve the search syntax by including further upcoming food technologies. In this regard, literature reviews are never complete as new insights are constantly being gained and published, and therefore must be updated regularly. Moreover, future reviews on that topic could also include grey literatures which were not part of this study. Hence, grey literature could give more insights for the industry perspectives as well as increase literature in the developing country context. Thus, systematic reviews could be used to identify factors at industry level (i.e. farmer, trader, processor, retailer) more comprehensively, e.g. cost-effectiveness could be an important factor for the food industry. The results of these reviews could be used to conceptualize food technology evaluation models at food industry level. As a further step, the outcomes of the different reviews could be used to develop a holistic model for analyzing several actors of the food chain.

Second, behavioral models like those used in this thesis are simplified to make them comprehensible (Darnton, 2008). In this regard, behavioral models are limited by its nature of being a concept that helps to understand behavior, but it does not demonstrate what makes people behave how they do (Darnton, 2008) – in other words, the "attitude-behavior gap" or also "value-action gap". Behavioral models are primarily investigated by cross-sectional survey designs. Thus, to better understand the decision-making process, future research could realize behavioral experiments. Besides the suggested between-group information treatment designs and experimental discrete choice modeling settings for evaluating 3D-printed food in section

4.5.3, future research could also consider discrete choice modeling for assessing other evaluation indicators, e.g. willingness to pay (with respect to stated preferences). Future studies could also consider longitudinal analysis of how acceptance or rejection changes in time. This could include the analysis of the implementation process of a concrete technology along the supply chain.

(c) Empirical approaches

The included empirical research within this thesis is limited by their settings:

- targeted supply chain actor: consumer and trader,
- type of technology: 3D-printed food, dietary supplements and improved packaging,
- data collected in: Germany and Tanzania.

These settings address the identified research gaps from the extensive literature review of chapter 2 and 3. Nevertheless, future research should investigate more on the research gaps, which are in more detail elucidated below.

First, one limitation concerns the types of respondents targeted in empirical research (i.e. consumers and traders). Although each chapter focuses on specific targeted group of respondents, the aspects investigated could also be relevant for other respondents. For instance, perceived usefulness of an innovation, as an adoption indicator for new food technology at industry level, was only examined among traders. Moreover, other stakeholder opinions are equally important. For example, food scientist and technologists are versatile practitioners for technological developments (Floros et al., 2010), and as experts in the field they can influence policymakers by communicating results out of science. Further, the evaluation of developments in the food system by policymakers may influence the final implementation strategy by, e.g. subsidies and regulations. Thus, it can be contended that policymakers could be in position to create an enabling environment for food chain actors to adopt such innovations in the agri-food sector. Future studies with these stakeholders could initially replicate a similar approach as proposed in this thesis, i.e. first conducting a systematic review for developing a model with important factors that can be tested in a second step. After examining and synthesizing relevant factors at each level of the supply chain, an evaluation study of one particular food technology, e.g. 3D food printer, along the supply chain could be conducted.

Second, the systematic literature reviews identified lack of research regarding the evaluation of biofortified or functional foods and processing technologies which should be investigated in future research. Moreover, to meet the challenges of food safety and security for the global population, more and more food (technology) innovations and ideas for the future food system

are coming up. For instance, in the future, the food industry may be able to process low value food and underutilized edible biomass back to their constituent macro- and micro-nutrients for further food production in line with the circular bioeconomy (Galanakis, 2012; Golembiewski et al., 2015). In addition, more food technologies such as synthetic biology and CRISPR/Cas (Katz et al., 2018), meat alternatives (e.g. in vitro meat[23]) as well as new food products are advancing by utilizing alternative sources of proteins such as seaweeds and insects (Tian et al., 2016). Others are radically rethinking agriculture in terms of urban vertical farming (Despommier, 2013; Farmers Cut, 2019) and forecasting alternative food networks (Burch & Lawrence, 2009; Cerrada-Serra et al., 2018; Sonnino et al., 2016). These upcoming technologies and innovations will require evaluation studies with respect to relevant chain actors. In addition, companies need to stay competitive by being innovative and adapting to the economy, e.g. adding competencies and changing business models (Cerrada-Serra et al., 2018) which offers a new field of future research.

Third, the empirical research of this research is limited to populations from Germany and Tanzania. As new food technologies are dependent on how they are culturally appropriate or acceptable for the respective population (Askegaard & Madsen, 1998; Augustin et al., 2016; Jermann et al., 2015; Musgrove & Fox-Rushby, 2006; Pieniak et al., 2009), future research requires country-specific investigations. Nevertheless, the empirical research can be considered to be transferable to similar research settings with comparable cultural backgrounds.

Nonetheless, this thesis has significantly contributed to missing but relevant knowledge concerning new food technology evaluation by different chain actors to reinforce the impact of developments in the food system on the macro-level outcomes.

[23] "Among meat alternatives, in vitro meat produced from stem cells is presented as an interesting process because it mimics natural meat, not only in shape and aspect, but also in biological composition because in vitro producers are supposed to artificially synthesize real muscle cells", Hocquette et al. (2015).

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Appendix

Content of appendix

Appendix A – Studies according to type of innovation, supply chain actor and applied model, in absolute (relative) numbers.

Appendix B – Extent of significant relationships between latent variables and food evaluation for each technology category in quantitative consumer studies.

Appendix C – Extent of significant relationships between latent variables and the specific dependent variables in quantitative consumer studies.

Appendix D – All significant relationships between latent and dependent variables (quantitative consumer studies).

Appendix E – List of studies included in the literature review.

Appendix F – Dimensions of perceived benefits and risks for 3D-printed food.

Appendix G – Constructs, items and statements for survey in chapter 4.

Appendix H – Questionnaires for survey in chapter 6 and 7.

Appendix A

Studies according to type of innovation, supply chain actor and applied model, in absolute (relative numbers)

			models		
			Attitude models: attitude model (AM), theory of reasoned action (TRA), theory of planned behavior (TPB) (10%)	**Behavioral health model:** protection motivation theory, health belief model (7%)	study-specific models (88%)
type of technology/innovation	**product innovation**	genetic modification (GM) (61%)	11 (6%) Ref: *AM: 27, 135, 136;* *TRA: 117;* *TPB: 27, 34, 61, 86, 104, 125, 132, 157*	2 (1%) Ref: PMT: 42 HBM: 174	105 (54%) Ref: 1, 3, 5, 6, 7, 8, 10, 11, 12, 13, 15, 16, 17, 19, 21, 22, 24, 26, 29, 31, 32, 33, 37, 38, 39, 40, 46, 47, 48, 49, 50, 54, 56, 57, 58, 59, 60, 64, 65, 66, 67, 68, 69, 70, 71, 72, 74, 76, 77, 78, 79, 80, 82, 83, 84, 85, 88, 89, 90, 91, 92, 99, 101, 102, 103, 105, 106, 107, 108, 109, 110, 112, 115, 116, 118, 119, 120, 122, 127, 130, 131, 133, 138, 140, 141, 144, 147, 149, 152, 153, 158, 160, 162, 163, 164, 165, 169, 176, 177, 178, 179, 180, 181, 182, 183
		non-GM biofortification (4%)	1 (1%) Ref: TPB: 161	3 (2%) Ref: PMT: 51, 113, 114	2 (1%) Ref: 123, 124
		fortification with food ingredients (24%)	4 (2%) Ref: TRA: 134, 166; TPB: 30, 128	5 (3%) Ref: PMT: 41, 43, 73, 75; HBM: 134	36 (19%) Ref: 2, 4, 9, 10, 14, 17, 20, 25, 28, 36, 44, 54, 55, 58, 63, 74, 81, 93, 94, 95, 96, 97, 98, 100, 126, 129, 143, 145, 146, 150, 167, 168, 170, 171, 172, 173
	process innovations	nano-technology (6%)	1 (1%) Ref: TPB: 35	0 (0%)	10 (5%) Ref: 18, 58, 87, 111, 139, 148, 151, 154, 159, 176
		irradiation (4%)	0 (0%)	1 (1%) PMT: 45	5 (3%) Ref: 53, 62, 74, 142, 175
		high pressure processing (3%)	0 (0%)	0 (0%)	4 (3%) Ref: 121, 137, 155, 156
		pulsed electric field (1%)	0 (0%)	0 (0%)	1 (1%) Ref: 155
		pre-gelatinization (1%)	0 (0%)	0 (0%)	1 (1%) Ref: 52
		not specified (1%)	0 (0%)	0 (0%)	1 (1%) Ref: 23
chain actors		farmer (6%)	0 (0%)	0 (0%)	12 (6%) Ref: 13, 15, 22, 56, 69, 72, 80, 92, 105, 149, 169, 179
		processor (1%)	0 (0%)	0 (0%)	2 (1%) Ref: 23, 160
		consumer (92%)	16 (9%) Ref: AM: 27, 135, 136; TRA: 117, 134, 166; TPB: 27, 30, 34, 35, 61, 86, 104, 128, 132, 157, 161	11 (6%) PMT: 41, 42, 43, 45, 51, 73, 75, 113, 114; HBM: 134, 174	143 (77%) Ref: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 16, 17, 18, 19, 20, 21, 24, 25, 26, 28, 29, 31, 32, 33, 36, 37, 38, 39, 40, 44, 46, 47, 48, 49, 50, 52, 53, 54, 55, 57, 58, 59, 60, 62, 63, 64, 65, 66, 67, 68, 70, 71, 72, 74, 76, 77, 78, 79, 81, 82, 83, 84, 85, 87, 88, 89, 90, 91, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 106, 107, 108, 109, 110, 111, 112, 115, 116, 118, 119, 120, 121, 122, 123, 124, 126, 127, 129, 130, 131, 133, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 150, 151, 152 , 153, 154, 155, 156, 158, 159, 162, 163, 164, 165, 167, 168, 170, 171, 172, 173, 175, 176, 177, 178, 180, 181, 182, 183

References (full citation see Appendix E):

ID	Short citation
1	Abdulkadri et al. (2007)
2	Ahn et al. (2016)
3	Ali et al. (2016)
4	Amin et al. (2013)
5	Amin, Ahmad et al. (2011)
6	Amin, Azad, Ahmad et al. (2014)
7	Amin, Azad, Gausmian et al. (2014)
8	Amin, Othman et al. (2011)
9	Annunziata et al. (2016)
10	Bäckström et al. (2004)
11	Baker, Burnham (2001)
12	Bardin et al. (2017)
13	Barham et al. (2014)
14	Barrena et al. (2017)
15	Basu, Qaim (2007)
16	Bekker et al. (2017)
17	Beltran et al. (2016)
18	Bieberstein et al. (2013)
19	Boecker et al. (2008)
20	Brecic et al. (2014)
21	Bredahl (1999)
22	Breustedt et al. (2008)
23	Brewin et al. (2009)
24	Canavari et al. (2009)
25	Carrillo et al. (2013)
26	Chema et al. (2006)
27	Chen (2008)
28	Chen (2011)
29	Chen (2011)
30	Chen (2017)
31	Chen et al. (2016)
32	Chen, Li (2007)
33	Connor, Siegrist (2011)
34	Cook et al. (2002)
35	Cook, Fairweather (2007)
36	Coppola et al. (2014)
37	Costa-Font, Gil (2008)
38	Costa-Font, Gil (2009)
39	Costa-Font, Gil (2012)
40	Costa-Font, Mossialos (2005)
41	Cox et al. (2004)
42	Cox et al. (2008)
43	Cox, Bastiaans (2007)
44	Cranfield et al. (2011)
45	Crowley et al. (2013)
46	Curtis, Moeltner (2007)
47	Curtis, Moeltner (2007)
48	De Liver et al. (2005)
49	De Steur et al. (2010)
50	De Steur et al. (2012)
51	De Steur, Mogendi et al. (2015)
52	De Steur, Odongo et al. (2015)
53	Deliza et al. (2010)
54	Ding et al. (2012)
55	Dobrenova et al. (2015)
56	Edmeades, Smale (2006)
57	Emberger-Klein et al. (2016)
58	Evans et al. (2010)
59	Florkowski et al. (1998)
60	Gaskell et al. (2004)
61	Ghoochani et al. (2017)
62	Giamalva et al. (1997)
63	Gineikiene et al. (2017)
64	González et al. (2009)
65	Govindasamy et al. (2008)
66	Grimsrud et al. (2004)
67	Grobe, Douthitt (1995)
68	Grunert et al. (2001)
69	Guehlstorf (2008)
70	Gutteling et al. (2006)
71	Hagemann, Scholderer (2009)
72	Han et al. (2015)
73	Henson et al. (2010)
74	Henson, Cranfield et al. (2008)
75	Henson, Masakure et al. (2008)
76	Hu et al. (2009)
77	Hudson et al. (2015)
78	Irani et al. (2002)
79	James, Burton (2003)
80	Kaup (2008)
81	Kavoosi-Kalashami et al. (2017)
82	Kikulwe, Birol et al. (2011)
83	Kikulwe, Wesseler et al. (2011)
84	Kim (2010)
85	Kim (2012)
86	Kim (2014)
87	Kim, Kim (2015)
88	Kimenju, de Groote (2008)
89	Klerck, Sweeney (2007)
90	Knight (2007a)
91	Knight (2007b)
92	Krishna, Qaim (2007)
93	Krutulyte et al. (2008)
94	Krutulyte et al. (2011)
95	Krystallis et al. (2008)
96	La Barbera et al. (2016)
97	Labrecque et al. (2006)
98	Landstrom et al. (2007)
99	Laros, Steenkamp (2004)
100	Lawless et al. (2012)
101	Legge, Durant (2010)
102	Lockie et al. (2005)
103	Lu et al. (2015)
104	Lu, Gursoy (2016)
105	Luh et al. (2014)
106	Lusk et al. (2004)
107	Lusk, Coble (2005)
108	Lusk, Rozan (2008)
109	Marques et al. (2015)
110	Martinez-Poveda et al. (2009)
111	Matin et al. (2012)
112	McFadden, Huffman (2017)
113	Mogendi et al. (2016)
114	Mogendi et al. (2016a)
115	Montuori et al. (2012)
116	Moon et al. (2007)
117	Mulder et al. (2014)
118	Napier et al. (2004)
119	Nayga et al. (2006)
120	Olofsson et al. (2006)
121	Olsen et al. (2011)
122	Onyango, Nayga (2004)
123	Oparinde et al. (2016)
124	Oparinde et al. (2016)
125	Oparinde et al. (2017)
126	Pappalardo, Lusk (2016)
127	Pardo et al. (2002)
128	Patch et al. (2005a)
129	Patch et al. (2005b)
130	Pino et al. (2016)
131	Poortinga (2005)
132	Prati et. (2012)
133	Qin, Brown (2007)
134	Rezai et al. (2017)
135	Rodriguez-Entrena, Salazar-Ordonez (2013)
136	Rodriguez-Entrena, Salazar-Ordonez, Sayadi (2013)
137	Romano et al. (2015)
138	Ronteltap et al. (2016)
139	Roosen et al. (2015)
140	Rosati, Saba (2000)
141	Saher et al. (2006)
142	Sapp, Downing-Matibag (2009)
143	Schnettler et al. (2016)
144	Scholten et al. (1991)
145	Segre et al. (2015)
146	Shan et al. (2017)
147	Siegrist (2000)
148	Siegrist (2007)
149	Siegrist (2016)
150	Siegrist, Stampfli, Kastenholz (2008)
151	Siegrist, Stampfli, Kastenholz, Keller (2008)
152	Simon (2010)
153	Sjöberg (2008)
154	Sodano et al. (2016)
155	Sonne et al. (2012)
156	Sorenson, Henchion (2011)
157	Spence, Townsend (2006)
158	Spence, Townsend (2007)
159	Steenis, Fischer (2016)
160	Sung, Hwang (2013)
161	Talsma et al. (2013)
162	Tanaka (2013)
163	Tenbült et al. (2008)
164	Thorne et al. (2017)
165	Titchener, Sapp (2002)
166	Tsai et al. (2010)
167	Tudoran et al. (2009)
168	Tudoran et al. (2012)
169	Useche et al. (2009)
170	Vecchio et al. (2016)
171	Verbeke et al. (2005)
172	Verbeke et al. (2009)
173	Verneau et al. (2014)
174	Vlontzos, Duquenne (2016)
175	Wandel, Fagerli (2001)
176	Yue et al. (2015)
177	Zepeda et al. (2003)
178	Zhang et al. (2016)
179	Zhang et al. (2017)
180	Zhang, Liu (2015)
181	Zheng et al. (2017)
182	Zhu, Xie (2015)
183	Zwick (2005)

Appendix B

Extent of significant relationships between latent variables and food evaluation for each technology category in quantitative consumer studies.

Latent Code name	Technology							
	Genetic modification		Non-GM biofortification		Fortification		Processing technology	
	absolute	*in %*	*absolute*	*in %*	*absolute*	*in %*	*absolute*	*in %*
Acceptance of the product/ technology	5	3%	0	0%	0	0%	0	0%
Willingness to pay/ price perception	6	4%	0	0%	0	0%	0	0%
Attitude towards the behavior	2	1%	0	0%	2	4%	2	3%
Attitude towards food safety	4	2%	0	0%	0	0%	2	3%
Attitude towards product/ technology	10	6%	0	0%	12	21%	12	19%
Attitude to environment	1	1%	0	0%	0	0%	0	0%
Perceived benefit/ convenience	11	7%	0	0%	6	11%	6	10%
Risk (perceived risk; risk acceptance)	19	12%	0	0%	3	5%	4	6%
Fear	0	0%	0	0%	0	0%	1	2%
Food neophobia	0	0%	0	0%	2	4%	2	3%
Impact on health/ perceived severity	11	7%	0	0%	5	9%	6	10%
Health consciousness	0	0%	0	0%	5	9%	5	8%
Response cost	0	0%	1	33%	1	2%	1	2%
Response of product efficacy	1	1%	0	0%	7	13%	7	11%
Perceived behvavioral control+self-efficac	8	5%	1	33%	5	9%	5	8%
Subjective norm	2	1%	0	0%	1	2%	1	2%
Self-identity	1	1%	0	0%	0	0%	0	0%
Trust in institutions	26	16%	0	0%	0	0%	2	3%
Religiousness/ ethical and moral concern	5	3%	0	0%	0	0%	0	0%
Information Assessment	38	23%	1	33%	1	2%	1	2%
Quality perception of product	11	7%	0	0%	1	2%	2	3%
Vulnerability	1	1%	0	0%	4	7%	4	6%
Enjoyment	0	0%	0	0%	1	2%	0	0%
Total number (without excluded)	***162***	***100%***	***3***	***100%***	***56***	***100%***	***63***	***100%***

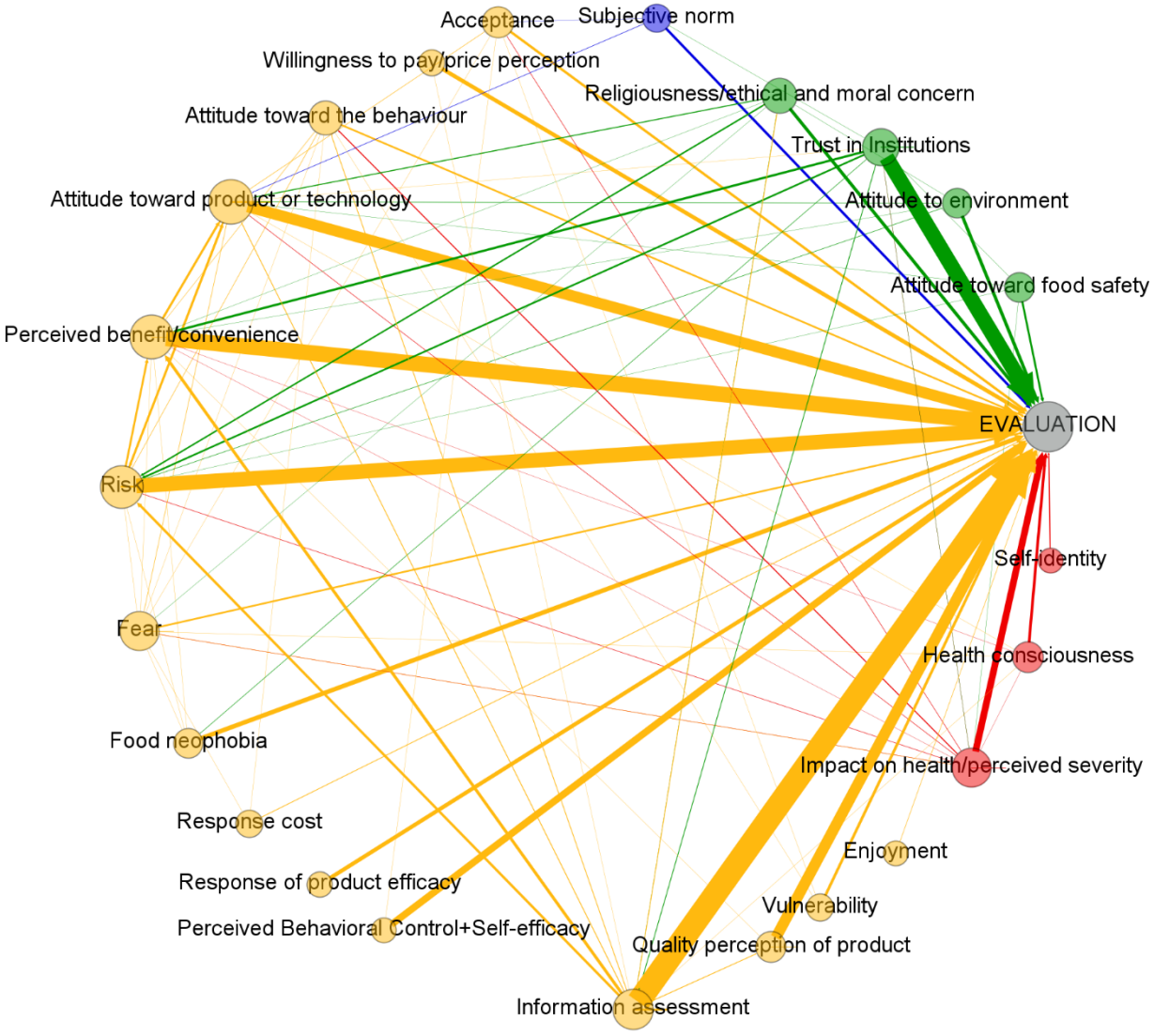
Appendix C

Extent of significant relationships between latent variables and the specific dependent variables in quantitative consumer studies.

Latent	Dependent											
Code name	Acceptance		Willingness to pay		Intention/likelihood		Attitude tow prod/tech		Perc. benefits & risks		all dependent variables	
	absolute	*in %*	*absolute*	*in %*	*absolute*	*in %*	*absolute*	*in %*	*absolute*	*in %*	*absolute*	*in %*
Acceptance of the product/ technology	**0**	0%	**3**	11%	**2**	2%	**0**	0%	**0**	0%	**5**	2%
Willingness to pay/ price perception	**0**	0%	**1**	4%	**2**	2%	**2**	4%	**1**	5%	**6**	3%
Attitude tow ards the behavior	**0**	0%	**1**	4%	**4**	3%	**0**	0%	**0**	0%	**5**	2%
Attitude tow ards food safety	**1**	6%	**0**	0%	**4**	3%	**1**	2%	**0**	0%	**6**	3%
Attitude tow ards product/ technology	**3**	18%	**3**	11%	**14**	11%	**1**	2%	**1**	5%	**22**	9%
Attitude to environment	**0**	0%	**0**	0%	**1**	1%	**0**	0%	**0**	0%	**1**	0%
Perceived benefit/ convenience	**1**	6%	**2**	7%	**7**	6%	**4**	8%	**3**	16%	**17**	7%
Risk (perceived risk; risk acceptance)	**4**	24%	**5**	18%	**8**	7%	**4**	8%	**3**	16%	**24**	10%
Fear	**0**	0%	**0**	0%	**1**	1%	**0**	0%	**0**	0%	**1**	0%
Food neophobia	**0**	0%	**0**	0%	**2**	2%	**0**	0%	**0**	0%	**2**	1%
Impact on health/ perceived severity	**0**	0%	**0**	0%	**15**	12%	**0**	0%	**2**	11%	**17**	7%
Health consciousness	**2**	12%	**0**	0%	**3**	2%	**0**	0%	**0**	0%	**5**	2%
Response cost	**0**	0%	**0**	0%	**2**	2%	**0**	0%	**0**	0%	**2**	1%
Response of product efficacy	**0**	0%	**0**	0%	**7**	6%	**0**	0%	**1**	5%	**8**	3%
Perceived behavioral control+self-efficacy	**0**	0%	**0**	0%	**13**	11%	**0**	0%	**1**	5%	**14**	6%
Subjective norm	**0**	0%	**0**	0%	**3**	2%	**0**	0%	**0**	0%	**3**	1%
Self-identity	**0**	0%	**0**	0%	**0**	0%	**1**	2%	**0**	0%	**1**	0%
Trust in institutions	**3**	18%	**0**	0%	**12**	10%	**11**	23%	**2**	11%	**28**	12%
Religiousness/ ethical and moral concern	**0**	0%	**0**	0%	**3**	2%	**2**	4%	**0**	0%	**5**	2%
Information Assessment	**1**	6%	**13**	46%	**7**	6%	**19**	40%	**3**	16%	**43**	18%
Quality perception of product	**0**	0%	**0**	0%	**9**	7%	**3**	6%	**1**	5%	**13**	6%
Vulnerability	**2**	12%	**0**	0%	**2**	2%	**0**	0%	**1**	5%	**5**	2%
Enjoyment	**0**	0%	**0**	0%	**1**	1%	**0**	0%	**0**	0%	**1**	0%
Total number (without excluded)	***17***	***100%***	***28***	***100%***	***122***	***100%***	***48***	***100%***	***19***	***100%***	***234***	***100%***

Appendix D

All significant relationships between latent and dependent variables (quantitative consumer studies).



Appendix E

List of studies included in the literature review.

1. Abdulkadri, A. O., Pinnock, S. E., & Tennant, P. F. (2007). Public perception of genetic engineering and the choice to purchase genetically modified food in Jamaica. *Journal of Food, Agriculture & Environment, 5*(2), p. 8–12.
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Appendix F

Dimensions of perceived benefits and risks for 3D-printed food.

Dimension	Benefits	Risks
Convenience	▪ Tasty and fresh food preparation in an easy, simple, cost-effective and time-efficient way (Sun et al. 2015b; Brunner et al. 2018). ▪ Applicable for various consumption situations, i.e. convenient take-away finger foods or proper meals served on a plate in various shapes (Brunner et al. 2018; Yang et al. 2017).	▪ At present, print cartridges and printer parts must be frequently cleaned and speed of printing is rather slow. ▪ 3D food printing could be time consuming and not offering any benefits over buying the food from the grocery store and then cooking the food (Crampton, 2018).
Naturalness	▪ Users can either place fresh ingredients into their printers or can buy pre-packaged food capsules made from real food (Lupton & Turner, 2018) ▪ 3D printed food is similar processed as other convenient food products.	▪ 3D print fosters partly an alienation of consumers from natural products because they need to get modified into printable forms/shapes (Keppner et al., 2018). ▪ Perception of 3D-printed food as artificial food (Gayler et al., 2018; Tran, 2016).
Socio-economic	▪ 3D food printers can simplify customized food supply chains by companies being able to replace multiple steps in food production (Dankar et al., 2018; Sun et al., 2015a). ▪ It is an economical and efficient technique of mass personalization, e.g. flavor, shapes and ingredients. ▪ Ingredients for the 3D food printer are easy to transport even to the most remote corners of the world or into space (Izdebska & Zolek-Tryznowska, 2016).	▪ Potentially higher cost than that of food products from mass production due to printing platforms (hardware and software) and printing materials, labor cost, operation cost, and general overhead for maintaining the production facility (Sun et al., 2015b). ▪ Recently, the efficiency of current food printers is too slow and cannot meet consumer requirements (Sun et al., 2015b).
Environment	▪ 3D printing food can provide a high-quality protein diet without increasing stress on arable land or fishing farm (Izdebska & Zolek-Tryznowska, 2016; Sun et al., 2015b). ▪ Reducing the ecological footprint by using fewer raw materials, less water and energy (Dankar et al., 2018). ▪ 3D food printing may decrease the amount of food waste due to merging multiple steps during processing into one step and food will not be manufactured unless it is ordered (Dankar et al., 2018).	▪ In the case that everyone 3D-prints his or her own food, the process of food production and therewith agricultural practices will completely change or replaced by 3D food printers (Tran, 2016).
Health	▪ 3D food printing may provide personalized food that precisely fit the needs, taste and dietary pattern of people (Dankar et al., 2018). ▪ Allows the food content to be adapted to personal lifestyle (e.g. the avoidance of certain ingredients, a vegan diet, etc.), medical recommendations (e.g. allergen exclusion, a weight-loss diet, etc.) (Brunner et al., 2018) ▪ Prepare food for elderly people who have mastication and swallowing problems (Dankar et al., 2018).	▪ Concern about the uncertainty of permanent changes in the human body if eating habits are long-term modified to strictly consuming 3D-printed food due to limited understanding of human nutritional needs (Grynol 2013; Tran 2016).

Appendix G

Constructs, items and statements for survey in chapter 4.

Latent variables	Manifest Variables		Scale	Source
Subjective knowledge	SKNOW01	I know pretty much about 3D food printing.	5-options: 1=strongly agree; 5= strongly disagree	Flynn, Goldsmith 1999
	SKNOW02[r]	I do not feel very knowledgeable about 3D food printing.		
	SKNOW03	Among my circle of friends, I am one of the "experts" on 3D food printing.		
	SKNOW04	I have already dealt with 3D food printing.		
	SKNOW05[r]	Compared to most other people, I know less about 3D food printing.		
	SKNOW06[r]	When it comes to 3D food printing, I really do not know a lot.		
Objective Knowledge	OKNOW01	It is a digitally controlled, robotic construction process.	True- false	Based on extended literature
	OKNOW02	3D printed food is built up layer by layer.		
	OKNOW03	So far it is not possible to print food products.		
	OKNOW04	For the printing process, no natural food can be used.		
	OKNOW05	During the printing process, a food paste is pressed through a nozzle.		
	OKNOW06	The printing materials have to be available as liquids or powders.		
	OKNOW07	3D food printer can cook food.		
	OKNOW08	The design of the food is created at a computer.		
	OKNOW09	Any food can be 3D printed.		
	OKNOW10	A 3D food printer is a printer whose cartridges are filled with food.		
Perceived Benefits	PB01C	3D food printer offer great benefits to the design of food according to personal optical preferences.	1=strongly agree; 5= strongly disagree	New
	PB02C	3D food printer offer great benefits to the time saving of preparing food.		Brunner et al. 2018
	PB03C	3D food printer are advantageous to the easiness of food preparation.		New
	PB01N	3D food printer are beneficial to the convenience of preparing food in everyday life.	1=strongly agree; 5= strongly disagree	New
	PB02N	3D food printer offer great benefits to the time saving of preparing food.		
	PB03N	3D food printer are advantageous to the easiness of food preparation.		
	PB01EC	3D food printer are beneficial to the economy.	1=strongly agree; 5= strongly disagree	Prati et al. 2011
	PB02EC	3D food printer offer great benefits to the society.		
	PB03EC	3D food printer are advantageous to the efficiency in food production.		Dankar et al. 2018
	PB01EN	3D food printer are beneficial to the environment.	1=strongly agree; 5= strongly disagree	New
	PB02EN	3D food printer offer great benefits to the ecological footprint of food production.		Dankar et al. 2018
	PB03EN	3D food printer are advantageous to the reduction of food waste.		
	PB01H	3D food printer are beneficial to the human health.	1=strongly agree; 5= strongly disagree	Dankar et al. 2018
	PB02H	3D food printer offer great benefits to a healthy food consumption.		

Latent variables	Manifest Variables		Scale	Source
	PB03H	3D food printer are advantageous to personal requirements in food consumption.		
Perceived Risks	PR01C	3D food printer are harmful to the convenience of preparing food in everyday life.	1=strongly agree; 5= strongly disagree	New
	PR02C	3D food printer involve considerable risk to the time saving of preparing food.		
	PR03C	3D food printer are disadvantageous to the easiness of food preparation.		
	PR01N	The 3D food printer is detrimental to the naturalness of processed foods.	1=strongly agree; 5= strongly disagree	New
	PR02N	3D food printers pose a significant risk to fresh food preparation.		
	PR03N	3D food printers are disadvantageous for the preparation of natural meals.		
	PR01EC	3D food printer are harmful to the economy.	1=strongly agree; 5= strongly disagree	New
	PR02EC	3D food printer involve considerable risk to the society.		
	PR03EC	3D food printer are disadvantageous to the efficiency in food production.		
	PR01EN	Applying 3D printing to food production is harmful to the environment.	1=strongly agree; 5= strongly disagree	New
	PR02EN	3D food printer involve considerable risk to the society.		
	PR03EN	3D food printer are disadvantageous to the efficiency in food production.		
	PR01H	3D food printer are harmful to the human health.	1=strongly agree; 5= strongly disagree	New
	PR02H	Applying 3D printing to produce food products involve considerable risk to a healthy food consumption.		
	PR03H	3D food printer are disadvantageous to personal requirements in food consumption.		
Attitude toward product/ technology		For me to consume 3D-printed food would be		Ajzen 2006
	A01 [r]	harmful (1) - beneficial (5)		
	A02 [r]	unpleasant (1) - pleasant (5)		
	A03 [r]	worthless (1) - valuable (5)		
	A04 [r]	irresponsible (1) - irresponsible (5)		
	A05 [r]	foolish (1) - wise (5)		
	A06 [r]	negative (1) - positive (5)		
Trust in institutions	How much trust do you have in the following institutions that they are conscious of their responsibilities in doing 3D food printing or handling 3D printed food products?			
	T01	Universities	a lot of trust (1) - no trust at all (5)	Siegrist, 2000
	T02	Private research institutions		
	T03	Food companies		
	T04	European Food Safety Authority (EFSA)		
	T05	Food Safety Department of the German Federal Institute for Risk Assessment		New
	T06	Restaurants		Siegrist 2000
	T07	Retailers, food distributors		
Subjective Norm	SN01	Most people who are important to me think that I should try/consume 3D-printed food.	should (1) - should not (5)	Ajzen 2006
	SN02	The people in my life whose opinions I value would approve that I try/consume 3D-printed food.	approve (1) - disapprove (5)	
	SN03	People who are relevant to me would influence my intention to consume or not to consume 3D-printed food.	likely (1) - unlikely (5)	

Latent variables	Manifest Variables		Scale	Source
	SN04	Most people who are important to me would try/consume 3D-printed food.	completely true (1) - completely false (5)	
	SN05	The people in my life whose opinions I value would eat - not eat 3D printed food.	eat (1) - not eat (5)	
	SN06	The intention to consume 3D-printed food of people who are relevant to me is determined by the views of me.	likely (1) - unlikely (5)	Cook et al. 2002
Perceived behavioral control (incl. Self-efficacy)	PBC01	If I wanted to, I could identify 3D printed food.	definitely (1) - never (5)	Cox et al. 2004
	PBC02	For me to consume 3D-printed food would be possible.	possible (1) - impossible (5)	
	PBC03	I am convinced that I can eat 3D printed food.	definitely true (1) - definitely false (5)	Ajzen 2006
	PBC04	I could easily learn how to print 3D food.	strongly agree (1) - strongly disagree (5)	New
	PBC05 [r]	How much control do you believe you have over purchasing and consuming 3D-printed food?	no control (1) - complete control (5)	
	PBC06	It is mostly up to me whether or not I consume 3D-printed food	strongly agree (1) - strongly disagree (5)	Ajzen 2006
	PBC07	When I print my own food, I would have the control about the food production.	strongly agree (1) - strongly disagree (5)	New
Intention to consume	I01	I am willing to consume 3D-printed food because a convenient food production is possible.	1=strongly agree; 5= strongly disagree	New
	I02	I would eat 3D printed foods if they are natural.		
	I03	I would eat 3D-printed food because of the socio-economic benefits.		
	I04	I am willing to eat 3D-printed food due to its environmental benefits.		
	I05	I would consume 3D-printed food because this food production has health benefits.		
	I06	Overall, I would eat 3D-printed food as soon as I see it in the market.		
	I07	The study made me aware of 3D-printed food and I want to try it now.		
	I08	I would eat 3D-printed food only for the chance for testing/ experiment.		
	I09	I would consider to implement 3D-printed food in my daily life.		
	I010 [r]	I do not plan to consume 3D-printed food.		
	I011	If a friend would offer me 3D-printed food, I would eat it.		
	I012	I would buy 3D-printed food in my preferred supermarket.		Ajzen 2006
	I013	I would order 3D-printed food in a restaurant.		New
	I014	I intend to buy a 3D food printer.		Ajzen 2006
	I015	Would you eat 3D printed food?	Yes; no	New

Latent variables	Manifest Variables		Scale	Source
Innovativeness	INNO01	Other people come to me for advice on new technologies.	1=strongly agree; 5= strongly disagree	Parasuraman 2000
	INNO02r	It seems my friends are learning more about the newest technologies than I am. (reverse coded)		
	INNO03	In general, I am among the first in my circle of friends to acquire new technology when it appears.		
	INNO04	I can usually figure out new high-tech products and services without help from others.		
	INNO05	I keep up with the latest technological developments in my areas of interest.		
	INNO06	I enjoy the challenge of figuring out high-tech gadgets.		
	INNO07	I find I have fewer problems than other people in making technology work for me.		
Ecological Worldview	NEP01	We are approaching the limit of the number of people the earth can support.	1=strongly agree; 5= strongly disagree	Dunlap et al. 2000
	NEP02r	Humans have the right to modify the natural environment to suit their needs. (reversed)		
	NEP03	When humans interfere with nature it often produces disastrous consequences.		
	NEP04r	Human ingenuity will insure that we do NOT make the earth unlivable. (reversed)		
	NEP05	Humans are severely abusing the environment.		
	NEP06r	The earth has plenty of natural resources if we just learn how to develop them. (reversed)		
	NEP07	Plants and animals have as much right as humans to exist.		
	NEP08r	The balance of nature is strong enough to cope with the impacts of modern industrial nations. (reversed)		
	NEP09	Despite our special abilities humans are still subject to the laws of nature.		
	NEP10r	The so-called “ecological crisis” facing humankind has been greatly exaggerated. (reversed)		
	NEP11	The earth is like a spaceship with very limited room and resources.		
	NEP12r	Humans were meant to rule over the rest of nature. (reversed)		
	NEP13	The balance of nature is very delicate and easily upset.		
	NEP14r	Humans will eventually learn enough about how nature works to be able to control it. (reversed)		
	NEP15	If things continue on their present course, we will soon experience a major ecological catastrophe.		
Food Involvement Scale	FIS01r	I don’t think much about food each day. (reversed)	1=strongly agree; 5= strongly disagree	Bell, Marshall 2003
	FIS02r	Cooking or barbequing is not much fun. (reversed)		
	FIS03	Talking about what I ate or am going to eat is something I like to do.		
	FIS04r	Compared with other daily decisions, my food choices are not very important. (reversed)		
	FIS05	When I travel, one of the things I anticipate most is eating the food there.		
	FIS06	I do most or all of the clean up after eating.		
	FIS07	I enjoy cooking for others and myself.		
	FIS08r	When I eat out, I don’t think or talk much about how the food tastes. (reversed)		
	FIS09r	I do not like to mix or chop food. (reversed)		
	FIS10	I do most or all of my own food shopping.		
	FIS11r	I do not wash dishes or clean the table. (reversed)		
	FIS12	I care whether or not a table is nicely set.		
Open question		After this survey, what do you think about 3D printed food? Here is space for writing down your thoughts.		New

Socio-economic questionnaires		
Label	**Questionnaire**	**Answer options**
EDU	What is your highest level of school education you have completed?	General school education; practical education; academic education; none of them.
FAMSTATUS	Please indicate your actual family status	single; domestic partnership; married; divorced; separated; widowed
EMP	Please indicate your actual employment status	full-time employment; part-time emplyoment; in training (e.g. school, university, vocational training); retired; homemaker; unemployed; other: _____
HHINC	Please indicate your approximately household income per month (total net income).	less than 1300€; 1300-1700€; 1700-2600€; 2600-3600€; 3600-5000€; 5000€ or more
SHOP	Where do you tend to buy your groceries from?	In supermarkets (Rewe, Edeka, Kaiser's, Tengelmann, Kaufland); discount (z.B. Aldi, Penny, Lidl, Netto, Norma); food specialist shop; weekly market; department store; organic grocery store/ organic farmer; organic supermarket; direkt marketer/ farm shop; in a small food retail store; health food store; by mail order/ catalog; delicatessen shop; food sales driver; internet.

Appendix H

Questionnaires for the survey in chapter 6 and 7.

The survey underlying in chapter 6 and 7 was introduced by enumerators to the traders with the following context:

In the tomato value chain in Arusha high postharvest losses are recorded due to the use of rough wooden crates for transportation, resulting in damaged crops. To protect the tomato crop from the rough wood, a lining in wooden crate could be used. Brown paper with holes can be used as lining and is easily available in a paper shop in Arusha town (TZS 400 per wooden box). Through lining, the damage can be reduced by 6-7% per crate and considering the cost for the lining, a profit increase of 3 % can be immediately achieved through using paper lining in the low season (in monetary values: TZS 1,300 in low season (when prices are high) – for 100 crates sold that means TZS 130,000 additional income per day). Comparing this additional benefit with labor costs for loaders, the additional profit per crate (TZS 1,300) is higher than the labor costs of a loader for one crate (TZS 400). In the high season (when prices are low), paper lining reaches up to 1 % profit increase, which means lower benefit (TZS 130 per crate) than in the low season but still reduce of damaged tomatoes. Using paper lining is profitable, increase income and will reduce postharvest losses.

Questionnaires (in addition to Table 7.3)					
May I go on with the interview?	Yes			No	
What is your role in the tomato Value Chain?	Wholesaler	Broker/ Commission Agent	Wholesaler + Broker/ Commission Agent	Village Collector	Retailer

Latent construct	**Statement**	**Scale**
Technology Readiness Index (Parasuraman, 2000)	Using wooden crates with lining makes me more efficient in my occupation as a trader/ *retailer*.	5-Likert scale
	I like the idea of increasing my profits by using wooden crates with lining.	
	I feel confident that I can reduce postharvest losses through usage / *buying* of wooden crates with lining.	
	Other people come to me for advice on new improvements for tomato packaging.	

Latent construct	Statement	Scale
	In general, I am among the first in the circle of important others to implement/ *buy new improvements for tomato packaging when it appears.*	
	I enjoy the challenge of figuring out new modes of packaging and its benefits.	
	Wooden crates with lining are not designed for use by traders.	
	The wooden crate with lining is too complicated to be useful.	
	I do not like to change the handling with standard wooden crate.	
	I worry that retailer will not pay higher prices for wooden crates with lining./ *I worry that the price for wooden crate with lining will be too high.*	
	I do not believe that lining will reduce tomato losses during transportation	
	I am not sure if the wooden crates with lining will be accepted by other actors in the tomato value chain.	
Problem awareness	I agree that postharvest losses during transportation in the tomato value chain are high.	5-Likert scale
	I believe that reducing losses increase income.	
	Packaging is a main cause of postharvest losses.	
	I think the standard wooden crates are not good as they are.	
	I think weight is the main problem of tomato losses.	
	I think the use of rough wood for tomato packaging contributes to high tomato losses.	
	I think dropping more tomatoes on top contributes to high tomato losses.	
	I think that standard wooden crate have to be improved.	
	I think the material of wooden crates need to be changed.	
	I think the size of the wooden crates need to be changed.	
	I think that wooden crates with lining are a good option to reduce postharvest losses.	
	I think I am the most responsible person for reducing postharvest losses in the value chain.	
Perceived Net Benefits	I believe improved packaging can increase profits.	5-Likert Scale
	I believe improved packaging is cost effective, when prices for tomatoes are high (in low season (Mar-May)).	
	I believe improved packaging is cost effective, when prices for tomatoes are low (in high season (Sept-Nov)).	
	I believe improved packaging can reduce costs of postharvest losses.	

Demographic and explanatory questionnaires	
Socio-Economics	What is your age?
	What is your gender?
	What is your education level? [Number of years]
	How long have you been a trader (from last year on)? [year]
	How long have you been a tomato trader (from last year on)? [year]
	Do you own your business or are you employed – right now?
	Do you use/*buy* right now standard wooden crates for transportation?

Demographic and explanatory questionnaires
If Q 87 yes: For how long have you used standard wooden crates from now on? [year]
If Q 87 yes: Where do you buy your standard wooden crates? [location]
If Q 87 no: Which other packaging do you use? [please specify]
Do you use wooden crates with any lining already?
If Q 91 yes: For how long have you used wooden crates with lining from now on? [year]
Have you heard about the wooden crates with lining before?
What is your main source of information about new packaging for tomatoes?
Are you interested in returnable plastic boxes?
From whom have you mostly bought your produce in the last 12 month?
To whom have you mostly sold your produce in the last 12 month?
How many hours do you take to complete one transaction? (Time from buying the produce up to selling totally) [transaction time in no. of hours]
When do you sell your produce?
How many crates have you sold in average in a week in the last high season, when prices are low (Sept-Nov 2013)? [no. of crates sold in average in a week]
How many crates have you sold in average in a week in the last low season, when prices are high (Mar - May/June 2014)? [no. of crates sold in average in a week]
What was your average price for selling one tomato crate in the last high season, when prices are low (Sept-Nov 2013)?
What was your average price for selling one tomato crate in the last low season, when prices are high (Mar - May/June 2014)?
Do you belong to any trader association or group?
Are you responsible for transportation? [Q105]
If Q 105 yes: How far do you have to transport the produce? [range of km - min and max]
If Q 105 yes: How do you usually transport when you transport the tomatoes?
If Q105 yes: What are the costs of transportation? [TZS]
How much postharvest losses do you have during transportation per transaction? [estimation in no. of crates]

Remark: Words in *italic* are different formulations in questions for retailers in comparison to wholesalers and village collectors.