Institut für Tierwissenschaften

System innovations promoting health management in pig production chains

Inaugural-Dissertation

zur

Erlangung des Grades

Doktor der Agrarwissenschaften

(Dr.agr.)

der

Landwirtschaftlichen Fakultät

der

Rheinischen Friedrich-Wilhelms-Universität

Bonn

vorgelegt am 09. April 2015

von

Sophia Veronika Schulze-Geisthövel

aus Hamm

Referent:	Prof. Dr. Brigitte Petersen
Korreferent:	Prof. Dr. Wolfgang Büscher
Tag der mündlichen Prüfung:	05.06.2015
Erscheinungsjahr:	2015

ABSTRACT

The main goal of this paper was to propose system innovations—referring always to the supply chain of pig meat—regarding realization of the following three big challenges: renouncement of tail docking, renouncement of piglet castration, and the reduction of antibiotic usage. The term system innovation is defined in Chapter 1 as the interaction of humans/software, technologies/hardware, and infrastructure/orgware and is illustrated in the subsequent chapters with concrete examples. Three empirical studies (Chapters 2–4) illustrate the different opinions of stakeholders in the meat sector on the three measures mentioned above. Chapter 2 shows the results of a study on the evaluation of the MRSA risk. The study is based on a combination of an online survey (249 participants) and an accompanying screening (157 participants).

Chapter 3 deals with the intercultural differences between Europe and China regarding the renouncement of docking tails. The results from the interviews with experts in the field and the structured operating audits in China (40 farms) were combined. Chapter 4 presents an evaluation of alternatives to piglet castration and is based on a study with 12 expert interviews. The results of the three studies clarify that a system migration can only be realized if there is a common commitment from all the participants within the value chain of meat, which at the same time guarantees the realization of the three measures mentioned above. The results of two experimental studies for improving the existing health management systems form the content of Chapters 5 and 6. As a first step, possible transmission pathways of MRSA and ESBL-E in the raising and mast phase of pigs was examined. As a second step, the yardmen were examined. For this, microbiological (molecular) investigations of samples from 86 people and 550 pigs, as well as 70 air samples, formed the foundational elements. Analyzing these foundational parameters showed a statistically securable correlation between the frequency of the occurrence of MRSA and ESBL-E. Chapter 6 exposes the results of a study about the definition of six key performance indicators for the outside control of boar fattening.

In addition, data from 294 boar farms within a period of two and a half years (608,466 numbers of supplied boars) were collected. The results of five different standardized trend curves in relation to smell deviation in the meat, the portfolios and the control charts for the risk estimate and process control, as well as a responsibility matrix, were suggested as four elements of visualization.

A matrix with 69 concrete system innovations is presented and described in Chapter 7, which builds the major result. The matrix simultaneously considers three different dimensions: humans, technologies, and infrastructure. Furthermore, it contains the four elements for innovation: product, service, competence, and component. From this the four crucial action fields for future studies are derived:

- Formation of the intercompany organization of audits and monitoring activities
- Visualization of results from risk analyses to occurrence and probability of discovery
- Identification of errors and disturbances during biological, technical, and organizational processes, as well as the definition from key indicators to the control
- Increase in intensive cooperation between science and practice using a common research and development database, as well as the use of simulation programs.

In summary, the better the animal holders are informed about changes in the system or are actively being integrated in research projects, the more their behavior toward proposed changes will transform into open-minded ideas.

Kurzfassung

Das Hauptziel dieser Arbeit war es, bezogen auf die Schweinefleisch erzeugende Wertschöpfungskette, Systeminnovationen im Hinblick auf die Realisierung der drei großen Herausforderungen, Verzicht auf das Kupieren der Schwänze, Verzicht auf die Ferkelkastration und Reduzierung des Antibiotikaeinsatzes, vorzuschlagen. Der Begriff Systeminnovation wird im einleitenden Kapitel 1 als Zusammenspiel von Mensch/ Software, Technologien/Hardware und Infrastruktur/Orgware definiert und in den Folgekapiteln mit konkreten Beispielen veranschaulicht. Drei empirische Studien (Kapitel 2-4) stellen die unterschiedlichen Haltungen von Stakeholdern in der Fleischwirtschaft zu den drei Maßnahmen dar. In Kapitel 2 werden die Ergebnisse einer Studie zur Einschätzung des MRSA-Risikos mithilfe einer Kombination von Online Befragung (249 Teilnehmer), sowie einer begleitenden Befragung zu einem Screening (157 Teilnehmer), dargestellt. Kapitel 3 geht auf die interkulturellen Unterschiede zwischen Europa und China beim Verzicht auf das Kupieren von Schwänzen ein. Verknüpft wurden bei der Auswertung Experteninterviews und strukturierte Betriebsaudits in China (40 Betriebe). Kapitel 4 stellt eine Bewertung von Alternativen zur Ferkelkastration vor, die auf einer Studie mit 12 Experteninterviews basiert. Die Ergebnisse aller drei empirischen Erhebungen verdeutlichen, dass nur über ein gemeinsames Engagement aller Beteiligten der Wertschöpfungskette Fleisch eine Systemumstellung realisiert werden kann und die gleichzeitige Umsetzungen der drei o.g. Maßnahmen möglich ist. Die Ergebnisse zweier experimenteller Studien zur konkreten Verbesserung bestehender überbetrieblicher Gesundheitsmanagementsysteme bilden die Inhalte der Folgekapitel 5 und 6. Zunächst wurden mögliche Übertragungswege von MRSA und ESBL-E in der Aufzucht- und Mastphase bei Schweinen und bei in den Ställen tätigen Personen untersucht und dargestellt. Hierfür standen unterschiedliche Untersuchungsmedien von 86 Menschen-, 550 Schweine- und 70 Luftproben für (molekular)mikrobiologische Untersuchungen zur Verfügung. Es besteht eine statistisch absicherbare Korrelation zwischen der Häufigkeit des Auftretens von MRSA und ESBL-E bei den Schweinen, der Stallluft und den in den Ställen tätigen Personen. Kapitel 6 zeigt die Resultate einer Studie zur Definition von sechs Key Performance Indicators zur überbetrieblichen Steuerung der Ebermast. Es wurden dazu Daten von 294 Ebermastbetrieben bezogen, auf einen Zeitraum von zweieinhalb Jahren ausgewertet (608.466 Anzahl gelieferter Eber) und die Ermittlung von 5 unterschiedlichen standardisierten Trendkurven bezogen auf die Geruchsabweichung im Fleisch, Portfolios und Regelkarten zur Risikoabschätzung und Prozesssteuerung sowie eine Verantwortungsmatrix als 4 Elemente der Visualisierung vorgeschlagen. Als zusammenfassendes Ergebnis im abschließenden Kapitel 7 wird eine Matrix mit 69 konkreten Systeminnovationen vorgestellt und erläutert. Die Matrix berücksichtigt gleichzeitig die drei Dimensionen Mensch, Technologie und Infrastruktur als auch die 4 Elemente für Innovationen: Produkt, Dienstleistung, Kompetenzen und Komponenten. Hieraus sind vier entscheidende Aktionsfelder für die Zukunft abgeleitet worden:

- Gestaltung der überbetrieblichen Organisation von Audits und Monitoringaktivitäten
- Visualisierung von Ergebnissen aus Risikoanalysen zu Auftretens- und Entdeckungswahrscheinlichkeit
- Identifikation von Fehlern und Störungen in biologischen, technischen und organisatorischen Prozessen sowie der Festlegung von Schlüsselindikatoren zur Steuerung
- Intensivere Zusammenarbeit zwischen Wissenschaft und Praxis, unter Einbezug einer gemeinsamen Forschungs- und Entwicklungsdatenbank sowie die Nutzung von Simulationsprogrammen.

Abschließendes Fazit ist: Je umfangreicher Tierhalter über Systemveränderungen informiert sind oder aber selber aktiv in Forschungsprojekte eingebunden werden, umso aufgeschlossener verhalten sie sich Veränderungsvorschlägen gegenüber.

Content

List of abbreviations

#	number
%	percent
€	euro
§	paragraph
°C	degree Celsius
AMOR	Alliances for the Mutual Organisation of Risk oriented inspection strategies
AmpC	AmpC Beta-Laktamasen
APP	actinobacillus pleuropneumoniae
APP2	actinobacillus pleuropneumoniae serotype 2
Art.	article
AUTO-FOM	Automatic Fat-O-Meater
BDA	BioDocAnalyze
Bes.	Activity
Bet.	Care
BfR	Federal Institute for Risk Assessment (Bundesinstitut für Risikobewertung)
BMELV	Federal Ministry of Food, Agriculture and Consumer Protection (Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz)
today: BMEL	Federal Ministry of Food and Agriculture (Bundesministerium für Ernährung und Landwirtschaft)
b-to-b	business-to-business
BUND	Association for the Environment and Nature Conservation Germany e.V. (Bund für Umwelt und Naturschutz Deutschland e.V.)
BVL	Federal Office of Consumer Protection and Food Safety (Bundesamt für Verbraucherschutz und Lebensmittelsicherheit)
CA	community acquired
ca.	circa
CA-MRSA	community-associated Methicillin-resistant Staphylococcus aureus
CC398	clonal complex
CCP	critical control points
CFU/m3	colony forming units per cubic meters
CO2	carbon dioxide
Comp	per compartment
CSR	Corporate Social Responsibility
CTX-M	cefotaximase-Munich -type ß-lactamase
DBV	German Farmers Association
DNA	deoxyribonucleic acid
dt	decitonne
E.coli	Escherichia coli

e.g.	lat. exempli gratia, for example
e.i.	id est
EFSA	European Food Safety Authority
EG	european community (Europäische Gemeinschaft)
EGO	producers' association Osnabrück (Erzeugergemeinschaft Osnabrück)
EQA	European qualification alliance
ESBL	extended-spectrum β-lactamases
ESBL-E	extended-spectrum ß-lactamases producing Enterobacteriaceae
et al.	lat. et alii, and others
etc.	et cetera
EU	European Union
FF	finishing
FMEA	failure mode and effects analysis
FR	farrowing
GERMAP	Report on the use of antibiotics and the dissemination of antibiotic resistance in human and veterinary medicine in Germany
GG	basic law (Grundgesetz)
h	Hour
H	Housing
HA	hospital acquired
HACCP	hazard analysis and critical control points
HA-MRSA	hospital-associated Methicillin-resistant Staphylococcus aureus
HCA-MRSA	healthcare-associated community Methicillin-resistant Staphylococcus aureus
HDE	Central Association of German Retailers
i.e.	lat. id est, that is
ICT	information and communication tools
IncN	Incompatibilitiy group N
ISO	International Organization for Standardization
IT	information technology
kg	kilograms
KPI	key performance indicators
LA	livestock-associated
LA-MRSA	livestock-associated methicillin-resistant Staphylococcus aureus
LANUV	office of a federal state for nature, environment, and consumer protection of North Rhine/Westphalia
m	meter
mA	milliamper
M. hyo	Mycoplasma hyopneumoniae
MALDI-TOF MS	mass spectrometry
MARAN	monitoring of antimicrobial resistance and antibiotic usage in animals in the Nether-

	lands
mecA	methicillin resistance determinant
mg	milligram
ml	milliliter
mm	millimeter
MRSA	Methicillin-resistant Staphylococcus aureus
MS	mass spectrometry
MSSA	Methicillin-sensitive Staphylococcus aureus
n	number
N	number
n total	total number
n.a.	not applied
n.d.	not determined
NF	nursery
No	number
OR	odds ratio
OXA	oxacillin resistant - type ß-lactamase
p	significance
PBP	penicillin binding protein
PCR	Polymerase-Chain-Reaction
PCV2	porcine circovirus type 2
PFGE	pulsed field gel electrophoresis
Pr / r	statistical correction with the species-specific correction factor
PRRS	porcine reproductive and respiratory syndrome
PRRSV	porcine reproductive and respiratory syndrome virus
QM	quality management
QPorkChains	Improving the quality of pork and pork products for the consumer: Development of innovative, integrated, and sustainable food production chains of high quality pork products matching consumer demands
QS	Quality and Safety GmbH (Qualität und Sicherheit GmbH)
rep-PCR	repetitive element PCR
S. aureus	staphylococcus aureus
SHV	sulfhydryl variable -type ß-lactamase
SI	serology index
SIV	swine influenza viruses
SNP	single nucleotide polymorphism
Spa-Typ	Staphylococcus aureus Protein A Gene Typing
SPSS	Statistical Product and Service Solutions
s	seconds
t	timepoint
TEM	temoneira-type ß-lactamase

tet	tetracycline resistance
TierSchG	Animal Welfare Law (Tierschutzgesetz)
TiGA	Animal Health Organisation (Tiergesundheitsagentur)
VDF	Meat Industry Association
VEZG-cost	Association of producer groups for livestock and meat e.V. (Vereinigung der Erzeugergemeinschaften für Vieh und Fleisch e.V.)
VO	regulation (Verordnung)
V	volt
W	growth
WLV	Westphalia-Lippe Agricultural Association
ZDS	Central Association of German pig production e.V. (Zentralverband der Deutschen Schweineproduktion e.V.)

1 General introduction

1.1 Introduction

A basic condition for producing high quality food, as well as contributing to active animal welfare, is the intercompany health management (Petersen et al. 2014). Illnesses during pig fattening represent processing restrictions and the residues from treatment present a high risk for the slaughter and processing stages. Even with different measures or procedures, the focus still remains on the well-being and health maintenance of the animal (Hörüger 2001). Today, most authors do not see animal well-being and animal health as separate from each other; instead, they are common tasks for animal keepers and veterinary surgeons in all phases of meat production, beginning with the birth of the animal up to its slaughter (Schulze Althoff 2006; Ellebrecht 2008; Düsseldorf 2013; Klauke 2013).

From this perspective, the expectations from society and consequently those of the consumer also have to be regarded. Changes in animal husbandry in connection with aspects of food quality and security and animal well-being and animal welfare, as well as the role that agriculture plays in society, have been described in scientific publications and evaluated from the viewpoint of different disciplines. An overview of studies in the subject area of animal welfare/animal well-being highlight the publications from the EU FAIR project "Consumer concerns about animal welfare and impact on food choice" (e.g. Harper and Henson 2001), Eurobarometer studies (2005, 2007, 2010), and the Welfare Quality project (e.g. Evans and Miele 2008), as well as the Q-PorkChains EU project (Bonneau et al. 2011). For the role of agriculture in society, three survey papers are itemized (Eurobarometer 2010, TNS Emnid 2012, Zander et al. 2013). Often investigations regarding grocery shopping and food labeling are considered separately by measures in animal husbandry and agriculture (Lassen et al. 2006, Christoph et al. 2012). Several studies have shown that fair keeping of animal is desired by many European countries as a sign of their population's ethical conceptions. Those countries that were questioned for this study also recognize the conflicts that emerge, on the one hand, from the advantages of hygienic and modern animal husbandry and, on the other hand, from the desire for natural and small rural animal keeping (Boogaard et al. 2010, 2011, Kayser et al. 2012, Klauke et al. 2013). Some authors determine a strong latent anxiety in certain consumer groups when food production is out of the conventional livestock production. This attitude can be triggered by communication and can have behavior effects (Harper and Henson 2001). Emnid questioning revealed that in Germany the handling of animals and transparency with food production, as well as food quality, are important demands of the population (TMS Emnid 2012). The production of high-quality food is evaluated just as highly as responsible handling of animals (DLG 2009, SGS Fresenius 2011, TMS Emnid 2012); regional origin (SGS Fresenius 2011) attains a somewhat smaller meaning than species-appropriate animal rearing (Zander and Hamm 2010). It is remarkable that in some studies the majority of interviewees felt ill-informed and desired more extensive information about the processes in animal and food production (Eurobarometer 2007, 2010). Currently, public discussion around animal husbandry is characterized by topics such as environmental requirements, animal welfare, and food security. Animal welfare is becoming socio-politically increasingly meaningful and affects the sales decisions of customers for pork meat. Meanwhile, statements about animal well-being are considered to be one of the most important goals in the quality policy from delivery chains to the food retail trade. This is one reason why enterprises of the agrarian sector, as well as participants of food production along the entire value-added pork chain, are more intensively occupied than before with the introduction of system innovations for animal well-being.

Based on Richter and co-authors (2014), system innovations are defined as:

> […] "technology-based innovations, which can be converted into economically sustainable products or services, if it succeeds to merge the necessary components and competencies into functioning system architectures and securing their social acceptance. Withal they overcome organizational and technical borders and are defined by a functioning cooperation of different stakeholders along value-adding processes and facilitate new successful business models."

In particular, for service facilities in pork production with a network coordinator function, system innovations are relevant since they frequently contribute to the quality policy of the whole supply chain (Brinkmann et al. 2011). However, Czekala and co-authors (2013) are of the opinion that sufficient experiences and organizational conditions for system innovations in pig farming are still missing. The renouncement of piglet castration without anesthetization, the reduction of antibiotic use, and the renouncement of tail docking belong to the demands of society and market partners in the value-added chain. In practice, these still need to be converted as fast as possible. Some authors point out that conversion for these demands is valid for developing the principle of organization of process innovations in the value-added chain of pork production (Bruns et al. 2014). The challenges consist of integrating high animal performance with biological-technical progresses in the procedures of animal husbandry, while combining the goals of environmental, animal, and consumer protection. Sustainable systems in animal husbandry, which share ecological viability, economic efficiency, and sociocultural acceptance as equally important goals, presuppose change processes within the production and a re-orientation of responsibilities within the delivery chain to the food retailer (Schön 2002; Düsseldorf 2013; O`Hagen 2014). In the context of the *Initiative Animal Welfare* (Initiative Tierwohl), which is operated by the trading partners, there are three measures that assume system innovation. They are discussed below.

The renouncement of tail docking

In many European countries it is routine practice in intensive pig rearing to dock the tails of piglets in their first days of life. This is done to prevent tail biting. The experiences of animal keepers with this method are that the absolute number of pigs that engage in tail biting can be reduced by tail docking. However, studies have shown that this measure does not completely eradicate behavior disturbances. Tail biting is not a monofactorial problem. Instead, it is a multifactorial problem behind which a whole complex of risk factors exists. Such risk factors are released by risk complexes that can be different in their combination from enterprise to enterprise (Knoop 2010, Pütz 2014, Schulze-Geisthövel et al. 2012 a, Freitag 2012, 2014, Jaeger 2013).

Cannibalism can result in losses during pig fattening. A preliminary stage in cannibalism is the so-called tail biting. It is an expression of disturbed behavior of pigs. This can manifest in the form of harmless suckling or licking of the tail, but can also include chewing or biting the tail off. This abnormal behavior can be found in both ecological and conventional husbandry. Infections, decreased performance, abscesses, or death can be consequences of tail biting, which are connected with substantial economic losses for the enterprise (Knoop 2010, Taylor et al. 2010).

Possible reasons for tail biting include poor life and/or husbandry conditions of domestic pigs. However, wild pigs, to safeguard their own survival and the survival of their species, contend with many challenges in their environment. In today's systems there are nearly no possibilities for domestic pigs to realize their innate species-appropriate behaviors; for example, foraging or setting up a hierarchy. Therefore, they develop behavior disturbances such as the biting of tails, ears, or flanks (Stafford 2010). If tail biting occurs and an animal bleeds, the blood attracts the remaining pigs in the stable and these also begin with the tail biting. Without the animal keeper intervening, the unrest and aggressiveness of the animals increase. The pigs will not stop the biting on their own (EFSA 2007, Knoop 2010).

The docking of piglet tails has become increasingly more criticized since the EU Directive 2001/93/EG changed the Directive 91/630/EWG regarding the minimum requirements for the protection of pigs after routine tail docking was forbidden. According to § 5 par. 3 No. 3 in connection with § 6 exp. 1 No. 3 of the animal protection law, interference in individual cases is permissible for the intended use of the animal, for its protection, or for the protection of other animals.

Meanwhile, a set of authors have demanded suitable individual operating measures in order to optimally counteract the occurrence of behavior disturbances in piglets and mast pigs (Pütz 2014, vom Brocke 2014, Madey 2014). For this it is also necessary that piglet producers, breeders, and fatteners cooperate. According to a study by Pütz (2014), the largest risk for the occurrence of tail biting exists during the growing phase. In addition, the production section of fattening must be arranged in such a way that pigs can access suitable manipulable material and that the behavior of the animals be adequately observed. Bite injuries on the tail of pigs have the danger of developing inflammation that can spread up the spinal column. Also, purulent abscesses can develop that are invisible from the outside. These abscesses, even in exceptional cases, can implicate a distortion in a carcass. Thus, the renouncement of tail docking in the first days of the piglet’s life requires system innovations for early recognition of behavior anomalies and injuries in the animals in each age group. For all involved participants in the meat production chain, this means reorientation and restructuring of its well known working procedures. A special challenge is the development of technical solutions for all usual farming techniques, which would make improved single animal observation and a fast response to critical situations possible.

Renouncement of piglet castration without anesthetization

The principal reason for routinely castrating pigs was contrary to other animal species. This measure was not to avoid aggressive behaviors or unwanted pregnancies, but rather to prevent the development of boar odor (Weiler et al. 2000, Font I Furnols et al. 2003). Castration of male suckling piglets prevents the occurrence of taste and smell deviations in the meat, which is found in sexually mature boars. Therefore, in the European Union boar meat is hardly brought to market. Both ethical and economic conflicts accompany the past practice of castration, because "the lack of acceptance of smell and taste deviating meat of boars opposes the animal welfare obligation to avoid pain, suffering, and damage to animals" (Link 2008).

In particular, piglet castration without anesthetization is seen as extremely critical. After difficult negotiations, the market partners agreed to abolish piglet castration. Agriculture therefore is seeking alternatives in order to bring the ethical requirements, social acceptance of modern animal husbandry procedures, as well as profitability of pig fattening into agreement. Male piglets—except rigs or breakage piglets—may be castrated according to the valid directives up to the seventh day of life without anesthesia (§ 6 Abs 1 in connection with § 5 exp. 3 No. 1 of the Animal Protection Act – TierSchG). However, all possibilities must be exhausted for decreasing any pain or suffering by the animals (§ 5 exp. 1 sentence 4 TierSchG). For pain suppression the so-called non-steroidal antiphlogistic agents are suitable with the active substance meloxicam or flunixin. While castration without anesthetization of male suckling piglets was inseparably connected with animal husbandry in the past and was not doubted by society, in recent times public perception on animal welfare has changed. It is no longer discussed whether piglet castration without anesthesia is forbidden, but rather which alternative procedure is best suited. There are different possibilities:

- surgical castration under analgesia (QS-standard)
- surgical castration under inhalation anesthesia
- surgical castration under inhalation anesthesia and analgesia
- fattening of young boars
- vaccination against boar odor

Some European countries (Norway and Switzerland) prohibit castration and have already converted. It can be assumed that in the foreseeable future castration will be completely forbidden on a long-term basis for the entire European Union. Surgical castration of piglets without anesthesia will be stopped in Germany on January 1, 2018.

There are various requirements for the alternatives; apart from the animal welfare and legal aspects, the practicality of these procedures also have to be considered. The measures should be performed by the animal keepers themselves in a facile, reliable, and economic manner and should be accepted by the public. In addition, this also includes a high quality of the final product.

It is currently accepted that boar fattening will represent the alternative procedure of choice on a long-term basis (BMELV 2011). The conversion to the fattening of boars means changes in intercompany management, testing, and sorting processes (O'Hagen 2014). All production and processing levels in the boar meat producing process are thereby merged into the system change. The fattener has to adapt his management for the more active male animals, observe them more attentively, and intervene quickly in critical situations.

More complex technical and organizational conversions are required during the slaughtering processes in order to recognize odor distinctive features from carcasses. This requires trained staff. Furthermore, stress factors during transport and in the waiting stable at the slaughterhouse must be recognized and prevented with appropriate measures. Stress directly before slaughter of the boars can increase the risk of smell deviations in the meat. Thus, the renouncement of piglet castration requires a system innovation that factors all of the involved participants of the value-added chain into it. It also requires the reorganization of intercompany testing processes.

Lowering the use of antibiotics for a reduction in multi-resistant zoonotic diseases

The very extensive reporting of antibiotic use in livestock husbandry, as well as the occurrence of multidrug-resistant pathogens in hospitals, is a further reason why system changes in animal production are shifting into the foreground. The decreased use of antibiotics in food-producing animals is not only due to the residue problem, but also the development and propagation of microbial resistance (Da Costa et al. 2013). Both extended-spectrum β-lactamases (ESBL) (Schmithausen et al. 2013a) and livestock-associated methicillin-resistant *Staphylococcus aureus* (LA-MRSA) have already been isolated—separate from each other—from different stages of the production chain (Schmithausen et al. 2013b, Petersen et al. 2014, Köck et al. 2013). Only limited knowledge is available about the kind of risk disclosure and risk perception within different social groups. In particular, the behavior of animal keepers and veterinary surgeons in handling antibiotics is regarded as a substantial cause in the accumulated occurrence of multidrug-resistant pathogens (Da Costa et al. 2013). At the same time, both occupational groups are classified as special risk groups and reservoirs and/or carriers of multidrug-resistant pathogenic agents, just like hospital staff, and therewith have a potential danger when it comes to postoperative infections (Wieler et al. 2011).

Antibiotics aid in the healing of bacterial illnesses. Bacterial infections that occur in livestock husbandry cannot be treated without antibiotics. Antibiotics are used in veterinary medicine with the aim of treating individual animals, groups of stock, or whole stocks in the early stage of the illness. For the safe handling of antibiotics, clear diagnostic identification, temporally defined therapy, and adherence to the prescribed inherent delays are indispensable for preventing antibiotic residual in the meat. Despite strict drug laws and regulations for the competent application of antibiotics, bacterial pathogens (e.g. *Escherichia coli* and *Staphylococcus aureus*) have become more insensitive to antibiotics over the last 10 to 15 years (Germap 2008). A bacterial pathogen is considered resistant to an antibacterial chemotherapeutic agent if the intrinsic concentration is not effective in restraining the pathogenic agent or killing it (Witte and Klare 1999). The risk of developing resistance increases with non-targeted application and low dosage, as well as long-term and stockwise use of antibiotics (Bundestierärztekammer 2010). With development of resistance of various pathogens, medicating animal and human infections will become increasingly more difficult (Germap 2008). According to Aubry-Damon et al. (2004), the treatment-resistant pathogens in humans and animals settle in the mucous membranes, which act as vectors for the resistance transmission. Therefore, epidemiologists and hygienists agree that the use of effective antimicrobial substances is not a replacement for optimal husbandry conditions, good management, and hygienic conditions (Bundestierärztekammer 2010). In fattening operations it frequently cannot be clearly resolved whether an infection with antibiotic-resistant pathogens took place in that enterprise or whether the animals were already infected with the pathogen at the piglet production company and/or in the rearing unit (De Neeling et al. 2007). According to De Neeling et al. (2007), pigs that are already settled in the piglet-producing enterprise or in the rearing enterprise with resistant agents, lead likewise to infection within the fattening operations. Further sources of MRSA are contaminated animal feed and dust particles (Friese et al. 2012). Furthermore, it is possible that a drug-resistant pathogen from a human host can colonize the pigs. The reverse is also conceivable. In the space of an enterprise, significant differences between different groups of MRSA-positive pigs are in posse. A possible reason for this is the transmission of MRSA within the group. If just one or a few MRSA positive animals exist in a stock group, there will be the possibility that the other animals are infected with the airborne pathogen (De Neeling et al. 2007). Gibbs et al. (2004) discovered MRSA within a pig-keeping company, as well as in the company's main wind direction. They classified the measured MRSA concentrations as alarming for human health. From this Green et al. (2006) concluded that a pig-keeping enterprise should be at least 200 m from the nearest housing complex in order to avoid air transmission of MRSA to humans. Therefore, according to De Neeling et al. (2007), farmers should carry in the pigsty a face mask and special shed clothes. In addition, to prevent transmission farmers should shower before coming into contact with other humans. The principles of production-accompanying hygiene and health management play an important role in avoiding infections and transmitting resistance characteristics in pig livestock. By decreasing the occurrence of infections in the livestock, a reduction in the quantity of antibiotics used can be obtained. This means optimizing husbandry conditions, as well as applying a meaningful vaccination strategy for the respective husbandry system (Düsseldorf 2013). The use of antibiotics is not a proven instrument to compensate for management errors, bad keeping conditions, unsatisfactory hygiene standards, or if it concerns a factor in secondary infections (Sundrum 1995; Striezel 2005; Waldmann and Wendt 2003; Haxsen et al. 2004). The effectiveness of an antimicrobial can become secured only by restrictive and responsible application. Antibiotic therapies that are non-targeted and incorrect favor the selection of treatment-resistant pathogens, as well as expansion of its resistance pool (Germap 2008). Different measures that aim to control and restrict antibiotic use are suggested by specialized organizations (EFSA 2008). In agreement with Sommer (2009), factors that can reduce the use of antimicrobial substances are, to a large extent, identical to factors that positively affect animal health and animal performance. The stability of livestock health is essentially based on maintaining three different aspects:

- Preventing pathogen entry from the outside
- Preventing propagation of the pathogenic agent within the livestock
- Strengthening the animals' resistance and lowering their stress levels

Measures for optimal hygiene in the pig husbandry differentiate between outside protection (biosecurity) and internal protection. Outside protection is concerned with preventing pathogens being introduced into the livestock. Internal protection is concerned with preventing pathogens from spreading within the livestock (Brede and Hoy 2010; Wilke et al. 2014). Both at the slaughterhouse and during the processing of pork meat the spread of multi resistant pathogens can be decreased by special attention to hygiene processes. Thus, system innovations are also necessary to reduce the use of antibiotics. The measures essentially refer to timely recognition of subclinical illnesses and a delay from one production stage to the next production stage (Knura-Deszczka 2000, Klauke 2013, Gymnich 2001), as well as the organization of all intercompany health care and monitoring systems (Düsseldorf 2013, Petersen 2013). Withal information and service agencies play a special role in the total chain from piglet production to slaughter (Schulze Althoff 2006, Schütz 2009, Ellebrecht 2008).

The nature of system innovations

Innovation systems exist on different levels; for example, regional (such as the innovation system of Bavaria or Thuringia), supranational (such as the innovation system of the European Union), or sectoral innovation systems (such as automobile construction or food production with respect to Germany) (Freeman 2002, Gerybadze et al. 1997, Bröring 2006, Bornkessel et al. 2014).

Innovation is a term that is used in everyday language. The term is associated with ‟new“: New products and services, new production procedures, new contract and organization forms, new channels of distribution. This already shows that innovation is more than only solving a technical problem. Innovations are very differently noticed and judged. Innovation is not objectively measurable; rather, it is a subjective term (Voßkamp 2002). In the scientific domain, the term innovation is difficult to define. There are a variety of approaches that attempt to define innovation (Bruns et al. 2014). A pragmatic definition is presented in Schumpeter's first book *Theory of the Economic Development*, which was published in 1912. In this book he does not yet speak of innovation, but of ‟the enforcement of new combinations“ that take place with intermittent, small improvement steps of an existing structure (Voßkamp 2002). Discontinuity means precipitous change, destruction of old balances, and replacement of the existing with the new. Schumpeter (1931) described five classes of new combinations:

"1. Production of a new item that consumer circles are not yet familiar with or a new quality or a property.
2. Introduction of a new method, that is, in the concerned branch of industry that is not yet familiar with the production method. It does not, by any means, need to be based on a scientific new discovery. It can assist in handling a commodity commercially in a new way.
3. Development of a new sales market; that is, a market on which the concerned branch of industry of the concerned country was so far not yet introduced to, irrespective of whether this market has previously existed or not.
4. Conquest of a new source of supply of raw materials or semi-manufacturers; again, indifferent whether this source of supply already existed before—it may have been neglected before or was considered inaccessible—or whether it must first be created.
5. Execution of a re-organization, like creating a monopolistic position or breaking through a monopoly."

Schumpeter did not use the term innovation before 1939 (Hauschildt 1997). Many further classifications of the term innovation can be found in the newer economic literature on innovation.

Process innovations must be differentiated from product innovations. A substantial difference between product and process innovations can be seen in the following point: Product innovations are implemented in the market. Process innovations are usually implemented internally; if one excludes the case that an enterprise offers its successfully realized process innovations to other enterprises in the market. Product innovations characteristically exhibit greater enforcement problems than process innovations. For product innovations, markets have to be created and payment-ready buyers converted, while process innovations can be enforced by arrangement by the management in the enterprise. The distinction between product and process innovations is not selective, however. Product innovations often need the introduction of new manufacturing processes in the enterprise. Thus, the introduction of process innovations enables product innovations. With service innovations, product and process innovations are not separable and rather are identical (Hauschildt 1997). The literature distinguishes between revolutionary and evolutionary innovations and between radical and incremental innovations. Revolutionary and/or radical innovations create completely new products and services and thus new markets. Evolutionary and/or incremental innovations consist of gradual improvements and small innovations of existing products and services. Those are, however, only very rough distinctions, which are connected with large delimitation problems (Voßkamp 2002). Objective, measureable sizes and clear rules for the reliable classification of an innovation into one of the two categories are missing (Hauschildt 1997). For rough evaluation of the degree of innovation possible measurable objective values can be "turned off": rate, extent, temperature resistance, and noise reduction etcetera. Important indicators of the changes in technical and economic effects include a precipitous increase in productivity, an increase in flexibility, space savings, and a reduction in energy consumption, etcetera (Grupp 1994). The concept of innovation systems is based on economic realization of the innovation. Innovations are often realized in a framework with feedback processes by interactions between different participants. Substantial characteristics of today's innovation processes are represented by cooperation between enterprises, as well as with research, and between enterprises and research establishments. Innovation processes exist today, for example, in supply chains that have a hierarchical, linear, and a systematically interactive organization.

Innovations are the basis of modern national economies, because they contribute to knowledge accumulation and learning processes. In addition, by providing new solutions they have the ability to improve the competitiveness and thus help to realize an increase in efficiency of the enterprise, as well as secure and strengthen the income and occupation of its employees. An innovation and/or an invention only becomes such if it is launched in the market. At this point the innovation either succeeds in the market or it fails. Innovation activities are not only technology based, but include all innovations of a technical, social, and organizational character (Bokelmann et al. 2012). There is a differentiation among product, process, and service innovations, as well as organizational innovations. The meaning of these different innovation types depend on the nation, region, sector, technology, and enterprise. Innovation activities can be based on creative scientific work (research), although this is not always necessary. Many gradual improvements (incremental innovations) result from feedback from customers or from improvements in the expiration of production processes. For this purpose, the experiences of the personnel and their readiness to make adjustments play a larger role than research and development. In contrast, new product or process developments are often based on research or, at least, development work for which a technical base is necessary. Innovation activity is usually affected by specific contexts; that is, the basic conditions in a country or in a sector, or in an enterprise that affects the extent, contents, and goals of the innovations. These basic conditions are dependent on different factors, such as the economic potential, the market conditions, supply and demand, the social requirements, as well as the creativity, human resources, knowledge base, and the infrastructure knowledge (Bokelmann et al. 2012).

System innovations are understood as an innovation that is oriented neither to given structures nor to given technical solutions. The technology no longer stands in the foreground, but is interlaced with the needs of the customer. Thus, according to Gantner (2011), three terms are relevant: humans, infrastructures, and technologies. The center of each system innovation is the individual needs of humans. The infrastructures are aligned with the individual needs of humans. Technologies serve the construction of infrastructures. Success in the market will thereby be attached not primarily by the technology, but by its customer-oriented conversion. System innovations can only be converted where knowledge and action are skillfully linked to new overall systems and/or their applications. It is valid to condense much information into usable knowledge, since a goal of system innovations is to use knowledge in favor of the customer (Gantner 2011).

The innovation process in the literal sense consists predominantly of in-house operational processes and activities, which take place in order to be able to realize an innovation. Additionally, the social welfare system affects the innovation directly (e.g. family needs, living situation). Again, innovation affects the organization (e.g. organization of the operational procedures). The innovation process in a narrow sense is dominated by the direct structures of an enterprise. Predominating components remain in the innovative phases, which give a content-related and temporal development to the innovation project. The innovation process in a strict sense substantially stretches the sphere of influence and effect. It heavily specifies external influences in, for instance, the agrarian-economic and political environments, as well as social environments. However, these are limited or not influenced at all (Buser 2006).

System innovations within agriculture

Authors who occupy themselves with innovations in agriculture place receipt of the competitive ability in the foreground. In addition, the lasting management of global megatrends such as security of food supply, climate change, shortage of natural resources, changing social requirements, and demographic change are mentioned in this context (e.g. Millennium Ecosystem Assessment 2005; IAASTD 2009). In order to master the associated challenges related to the megatrends and to use resulting opportunities, knowledge of existing innovation mechanisms is of central importance (Bokelmann et al. 2012).

Today, the introduction from microelectronics and information technology to the support of a set of processes is, in all industries, called the drivers of new development. In the opinion of some authors, the precision livestock farming approach has the possibility of developing sustainable animal farming through optimized husbandry conditions and a computer-aided quality assurance; with a simultaneous increase in productivity and a reduction in the building investments (Krommweh et al. 2014, Hoeck and Büscher 2013). The quintessential point of using computer-aided procedures is the supply and monitoring, as well as an automation of operational sequences (precision livestock farming), related to the single animal. In the last few years electronic animal identification has proven to be a key technology. Key technologies in precision livestock farming for single animal recognition must be economical and automatically readable and, as a check of animal origin, as fraud resistant as possible. Meanwhile, internationally standardized transponders are available in the form of electronic ear brands and injectable transponders. These new transponder variants are not only used in-house for process control, but also extra-operational for safe single animal marking (e.g. origin protection, premium nature, epidemic control). Since 1996, established international standards for electronic animal identification (ISO 11 784 and ISO 11 785) specify the codes for the animal number and permits the selection of half-duplex and full-duplex transponders with a uniform reader (transceiver). At present the construction of a new standard on the existing ISO standards for extended transponders with additional writes/readable memory and the integration of sensors (e.g. temperature), as well as authentication procedures, are worked out (Artmann 1999; Welz 1995).

With increasing stock sizes, higher animal performance, and higher requirements in animal welfare and food quality, computer-aided animal monitoring has become a central component in computer-aided husbandry procedures. The farmer is supported in his tasks with electronic monitoring of fodder admission, animal performance, and animal behavior, as well as animal health. Furthermore, the farmer can receive timely signals concerning unusual or critical situations in order to guarantee the appropriate response for nutrition and health maintenance of the animals. While the monitoring of certain parameters belong to fodder admission and the performance of standard equipment, monitoring of estrus events, animal behavior, and animal health is experiencing a slow entry into practice, notably for financial reasons (Schön et al. 2003).

However, the agrarian sector stands before a development leap. Digitization will lead in the coming years to substantial productivity progress. It will provide revolutionary challenges for agriculture. In Germany the dynamics of "smart farming" have been underestimated for a long time. The development is driven by a new generation of young, technology-friendly farmers and their expectations of the new digital technology. Digital innovations will be introduced to the entire system of farming in the next years and will include all regions and sizes of companies. A thrust will be connected with it toward business and profit-oriented agriculture. New trading areas lie within it, offering farmers integrated and system-independent total conceptions while ensuring the highest possible level of privacy. The digital changes in the rural sector will present opportunities for more economic and social sharing, easier entry into the worldwide agricultural commodity markets, better operating management, and a more efficient use of agricultural resources. Therefore, efforts toward digitization should be strengthened.

While computer-aided feeding procedures are already often used, the sensor-supported animal and quality control will gain strong significance. Computer-aided and automated procedures create a more species-appropriate group husbandry for all animals, while simultaneously supplying intensive single animal support and also as consistent adjustments as possible in the required keeping conditions of the animals (nature-related procedures). The philosophy to accurately seize and steer environmental and production data and thus afterwards differentiate the production process, as well as optimize it, is also valid for animal husbandry. Similarly, precision livestock farming refers to data acquisition from single animal, animal monitoring, feeding, and livestock management (Schön et al. 2001). In particular, the single animal identification and automated fodder retrieval systems are already used in pig husbandry—and have been for some years—to supply pigs individually with fodder after certain defaults and to supervise fodder consumption and animal performance. In further steps the already existing computer-aided partial procedures must be integrated into an overall system in which ecologically harmless and animal-friendly keeping conditions, as well as the genetic performance potential of the individual pig, can be exhausted. While in sow husbandry the single animal recognition is already often used, it does not play a significant role at present in the rearing of piglets or in pig fattening due to its cost.

In combining process control and regulation in every individual enterprise, and in the exchange of data between the involved participants from the different stages of the value-added chain, meat production hides an enormous potential for system innovations in the form of reorganized interactions of humans, technologies, and infrastructures (Schulze Althoff 2006, Ellebrecht 2008). The individual aspects in the subrange are not all entirely novel. It receives the innovation approach only if the partial aspects all meaningfully link with one another—in the sense of a system innovation—along the entire value-added chain. If cross company communications of all involved participants are recognized as an advantage, new customer requests such as the renouncement of tail docking, the renouncement of piglet castration without anesthesia, and a reduction in antibiotic treatments can be converted as a common quality management task.

1.2 Aims of research and research questions

An aim of this paper was to attentively consider the three great challenges facing future pork production:

- Renouncement of tail docking,
- Renouncement of piglet castration, and
- Reduced use of antibiotics.

For this purpose there was a need to determine and analyze any restricting or promoting factors in the conversion of each of these three goals, and in addition for all three in common. Moreover, concrete system innovations suggest that the human, infrastructure, and technology aspects should be considered simultaneously. The abovementioned measures affect management and verification processes in an animal-keeping enterprise, as well as in the further stages of the pork-production chain. For this reason the following fields of action were the focus of attention:

- Configuration of the enterprise-wide organization of audits and monitoring activities along the entire chain.
- Visualization of results of risk analysis respective to the occurrence of tail biting, smell deviations in meat, propagation of drug-resistant microorganisms in different biotopes (e.g. animal stable, slaughterhouse), and drug residuals in the meat.
- Identification of errors and disturbances during biological, technical, and organizational processes and defining the key indicators in controlling pork production.

With regard to the abovementioned three dimensions for system innovations, a matrix of measures was set up. The work essentially followed three research questions:

1. Why are system innovations envisioned in the pork-production chain?
2. What measures are necessary so that these are successfully implemented and/or accomplished?
3. How can these measures be optimally converted so that they bring lasting success?

To answer these questions, the results from five partial studies should be related to the dimensions and criteria for system innovations.

1.3 Structure of the present paper

This work is divided into seven chapters. Figure 1.1 illustrates that Chapters 2 to 6 are self-standing articles; three contain results from empirical studies and two contain results from experimental studies.

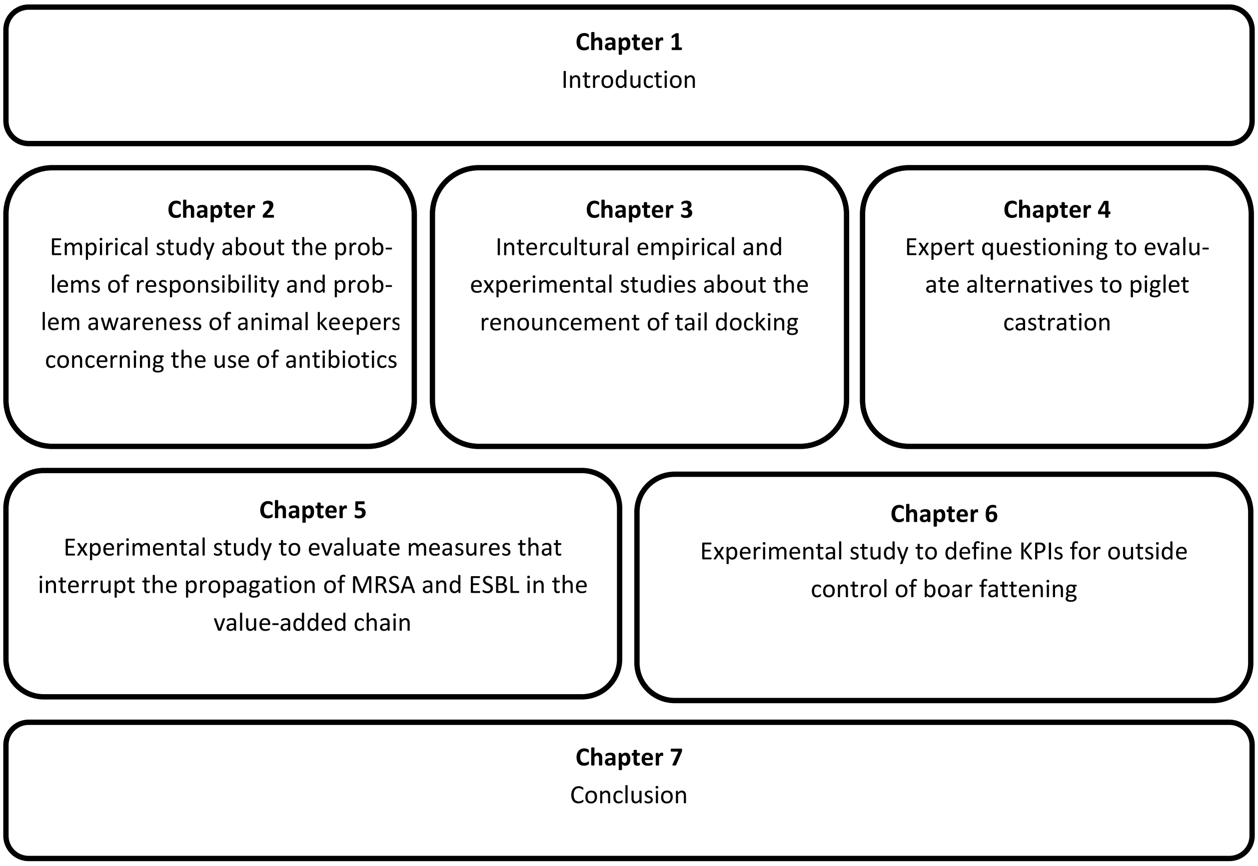


Figure 1.1: Structure of the current thesis

Table 1.1 gives a recapitulating overview of the methods, the range of the investigations and projects, as well as the programs that were used in each case and from where the partial studies were financed. Furthermore, the table shows to what extent the results in the chapters of this work were already published, either in total or in part.

Table 1.1: Overview of the individual chapters related to the methods, number of samples, status of publication and funding bodies

Chapter	Methods	Number of samples and/ or test people, as well as animals/enterprises	Status of publication	Funding bodies
Chapter 2 Empirical study about the problem of responsibility and problem awareness of animal keepers concerning the use of antibiotics	**Step 1** Development of a questionnaire Online survey with farmers Significance and correlation tests Portfolio **Step 2** Survey with farmers Sampling Significance and correlation tests	**Step 1** 249 farmers participated in the survey 124 completed it (49.80%) 101 participants could be taken into account for evaluation **Step 2** 157 farmers participated in the survey and the sampling	Will be submitted before the oral examination	Quarisma Marie Curie EU Projekt European Community's Seventh Framework Programme FP7/2007-2013 under grant agreement n°228821
Chapter 3 Intercultural empirical and experimental studies about the renouncement of tail docking	Structured audits 5 panels of experts Portfolios Main component analysis by SPSS	Experimental study: 20 tail-docking pig-holding enterprises 20 non-tail-docking pig-holding enterprises 5 expert workshops with participants from China and Germany (in total over 40 experts from science and practice)	This article has been published in German: Sophia Schulze-Geisthövel, Thorsten Klauke, Friedhelm Jaeger, Martin Hamer and Brigitte Petersen (2012): Vergleichende Strukturanalysen zur Charakterisierung von typischen Ursachenkomplexen für Verhaltensanomalie wie Schwanzbeißen beim Schwein innerhalb unterschiedlicher Haltungs- und Managementsysteme. In: Nutztierpraxis aktuell, Vol.41 S. 12-17	Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen
Chapter 4 Expert questioning to evaluate alternatives to piglet castration	Qualitative expert interviews on the basis of an interview guideline Questions regarding aspects of animal welfare Questions regarding the economics of the alternatives	plus 12 experts from all stages of the value- added chain (animal feed economy, piglet production, pig fattening, slaughter industry, and agricultural consultation)	This article has been published in parts in German: Sophia Veronika Schulze-Geisthövel, Michael Steinmann (2012): Wie sind die Alternativen zu bewerten? In: Fleischwirtschaft 11/2012, Vol.92 S.14-20	Edmund-Rehwinkel-Stiftung der Landwirtschaftlichen Rentenbank

Chapter	Methods	Number of samples and/ or test people, as well as animals/enterprises	Status of publication	Funding bodies
Chapter 5 Experimental study to evaluate measures that interrupt the propagation of MRSA and ESBL in the value-added chain	**MRSA** MALDI-TOF MS Antibiotic resistance testing Spa typing PCR detection of tetM and tetK **ESBL** MALDI-TOF MS Antibiotic susceptibility was determined on VITEK-2® PCR DNA isolation repPCR Pulsed field gel electrophoresis (PFGE) Enzymatic digestion of *E. coli* DNA **Statistics** Relative risk for ESBL and MRSA double colonization by Cochran-Mantel-Haenszel method Acquisition rates in the abattoirs by McNemar test Differences among abattoirs by Fisher´s exact test	**Step 1:** 35 farms 550 pigs 86 humans 70 air samples **Step 2:** Slaughterhouse 13 farms Samples were collected from three pigs per farm at three different time points: i) on the farm, ii) during slaughter (at 2 different abattoirs (A+B), and iii) on the carcasses deposited in the cold room of abattoir A	This article has been published in English: Ricarda Maria Schmithausen, Sophia Veronika Schulze-Geisthoevel, Franziska Stemmer, Mohamed El-Jade, Marion Reif, Sylvia Hack, Alina Meilaender, Gabriele Montabauer, Rolf Fimmers, Marijo Parcina, Achim Hoerauf, Martin Exner, Brigitte Petersen, Gabriele Bierbaum, Isabelle Bekeredjian-Ding (2015) Analysis of transmission of MRSA and ESBL-E among pigs and farm personnel. PLoS ONE Schulze-Geisthoevel, S., Schmithausen, R., Stemmer, F., El-Sade, M., Hoerauf, A., Exner, M., Bierbaum, G., Bekeredjian-Ding, I. & B. Petersen (2014) Occurrence of MRSA and ESBL in different habitats and different stages of the pork production chain. Vortrag, DACH Epidemiologietagung „Tiergesundheit und Ökonomie“ 3. - 5. Zürich / Schweiz	Forschungsnetzwerk Innovation durch Qualitätskommunikation FINQ NRW Cluster Ernährung wurde gefördert durch „Die Landesregierung Nordrhein-Westfalen“ und den „Europäischen Fond für regionale Entwicklung“.
Chapter 6 Experimental study to define KPIs for outside control of boar fattening	**Trend curves** Calculation of the proportional number of smell-deviating boars per slaughter date $= \frac{odor\ conspicuous\ boars}{slaughtered\ boars\ \ per\ slaughter\ da}$ Definition of an empirical limit of 3.7% smell deviations (limit definition in cooperation with slaughterhouses)	294 supplying enterprises of a slaughterhouse Slaughter data altogether 11.177 Boar deliveries: Period 1: Jan 2012–Jun 2014 Period 2: Jan	This article has been published in German: Lena Meinders, Sophia Schulze-Geisthövel, Hans-Jörg Eynck, Friedhelm Jaeger, Brigitte Petersen (2015): Visualisierung von Key Performance	Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen

Chapter	Methods	Number of samples and/ or test people, as well as animals/enterprises	Status of publication	Funding bodies
	Construction of 294 diagrams in Excel for determining trend curves **Principle of control charts:** Calculation of index values Categorization: 1 = fine 2 = medium 3 = worse Index: management holding of origin $\frac{\sum \boldsymbol{h1-j}}{\boldsymbol{N}}$ $h_{1\text{-}j}$ = sub-indices N= Number of groups Index: collecting yard $\frac{\sum \boldsymbol{y1-j}}{\boldsymbol{Ny}}$ $y_{1\text{-}j}$ = sub-indices Ny= Number of groups → Visualization by Excel Calculation of index values → Management holding of origin index → Collecting yard index Visualization by Excel **Portfolio** Regulation of odds ratios Gradual logistic regression Testing of correlation between health data and smell deviations Construction of a portfolio with „R 302" **Responsibilities matrix for a risk estimate** Allocation of competencies of participants in the meat-production chain (responsible, accomplishing, participating)	2012–Nov 2014 Number of supplied boars (in total 608.466) Odor deviations per slaughter date (in total 4177) 9 delivery enterprises with information of: Transport and collecting yard audit Index for working with key performance indicators Index for estimating possible risks Self-assessment index Outward distinctive features index Illness index *Salmonella* status index 9 delivery enterprises with information of: Farm audits Breed concerning unrest in the collecting yard Unrest in the collecting yard Group composition in the collecting yard Riding-up Rank fights Minutes for the first animals to lay down Minutes for all animals to lay down Recent skin injuries Health data of 294 delivery enterprises of a slaughterhouse **Husbandry-**	Indicators bei der Lieferantenbewertung in der Fleischwirtschaft. In: Bericht zur GQW-Jahrestagung 2015 Band 17/2015 Shaker Verlag S. 125-144. ISBN: 978-3-8440-3351-9	

Chapter	Methods	Number of samples and/ or test people, as well as animals/enterprises	Status of publication	Funding bodies
		caused organ findings Tail point necrosis Limb inflammation in the front and in the back Limb joint inflammation in the front and in the back **Infectious illnesses** Pleurisy < 10 % Pleurisy 10–30 % Pleurisy > 30 % Lung changes < 10 % Lung changes 10–30 % Lung changes > 30 % Retrospective procedures of data collection Production-accompanying procedures for the determination of measurement data		

The first chapter introduces the topic, describes the problems, and deals with the aims of the research and research questions of this work.

Chapter 2 describes two partial studies that are centered on the responsibility and problem awareness of different groups of animal keepers with regard to handling antibiotics and the risks associated with an increased occurrence of multidrug-resistant bacteria for not only their animals, but also their families.

Chapter 3 focusses on a comparative structural analysis for the characterization of typical causes for behavior anomalies—such as tail biting—among pigs in different husbandry and management systems in China. The chapter deals with the existing clear intercultural differences concerning the renouncement of tail docking.

In Chapter 4 alternative procedures to piglet castration without anesthesia are evaluated with consideration of ethical requirements, as well as social requirements and economic aspects. Experts answered interview questions about possible optional procedures regarding animal welfare, economy, and consumer acceptance. Calculations concerning the economy of the procedures show that boar fattening will likely be the best medium- to long-term alternative.

In Chapter 5 the methodical action and extensive interdisciplinary investigations are described for the prevalence and propagation of drug-resistant bacteria, as they are represented by MRSA and ESBL. Possible transmissions within the value-added meat chain, but also between human and animal, are common and are shown with the results from laboratory tests on extensive sample material.

In the study presented in Chapter 6, data from previous slaughters are computed by boar-supplying enterprises to predict the number of expected smell deviations during the current battle process. It is described with which methodological approach the assessment of suppliers and supplier promotion over consulting measures can be improved and which key performance indicators (KPI = key indicator) best reflect the common achievement of the slaughterhouse and its suppliers in the context of the system migration to boar fattening. Both the management of the origin enterprise and the health status of the boars are set in relation to smell deviations in meat and suitable KPIs for the outside process of boar fattening are suggested.

The concluding Chapter 7 summarizes all partial results of Chapters 2 to 6 in an overview matrix and provides answers to the research questions placed in Chapter 1. It ends with a view and recommendations for further research within the scope of system innovations in the pork production chain with the goal of improving animal well-being and decreasing the health risks for both humans and animals.

2 Survey on the risk awareness of pig and cattle farmers in relation to dealing with MRSA and antibiotics

SOPHIA VERONIKA SCHULZE-GEISTHÖVEL, ELISA-VALERIE TAPPE, RICARDA MARIA SCHMITHAUSEN, JAN LEPKOIJS, KATHARINA RÖTTGEN, BRIGITTE PETERSEN

University of Bonn, Faculty of Agriculture, Institute of Animal Science, Preventive Health Management Group, Katzenburgweg 7-9, 53115 Bonn, Germany

*Corresponding author: Sophia V. Schulze-Geisthövel.
Email: s.schulze-geisthoevel@uni-bonn.de

2.1 Abstract

For decades the danger regarding methicillin-resistant *Staphylococcus aureus* (MRSA) has been well known. While MRSA was initially only associated with hospitals, livestock-associated MRSA is being increasingly connected to the way food-supplying animals are treated. Still, little is known about the risk consciousness of farmers and their knowledge about MRSA difficulties.

Hence, the goal of this study was to obtain an opinion from people who are active in animal stables about their perceptions of MRSA. For this purpose, two successive studies were performed. Study I considered the attitudes of farmers toward the MRSA difficulty in relation to different life circumstances such as age, vocational education, and positive MRSA colonization within the closest family environments or held animal species. For this purpose 249 persons initially took part in an online survey, which resulted in 101 completely filled out questionnaires that could be statistically evaluated. The participants' educational level (p=0.042) and the animal species held on the farm (p=0.045) have a significant influence on a farmer's perception concerning the MRSA problem. People between the ages of 25 and 55 years, who are often in a farm's management position, seem to be less critically minded towards the possible dangers than younger or older farmers. Pig owners answered more risk consciously than cattle owners. Study II dealt with the connection of contact frequency with livestock and the risk of a possible MRSA colonization. A comparison of screening results from 157 participants showed that contact frequency (daily or irregular), as well as the branch of profession (animal owner/veterinarian opposite to advisor or relative with other professions), is significantly decisive for the prevalence of MRSA within the participants (contact frequency: p=0.000, branch of profession: p=0.000, OR=11.966). In this case, the risk for farmers and veterinarians is nearly 12 times higher than for other occupational groups.

The results show a high sense of risk consciousness and responsibility among farmers. However, it is assumed that most of the farmers who took part in the two studies were interested. For this reason the results should not be interpreted as the opinion of a broad mass of animal owners. After all, educational work is still needed. It can be concluded that compound projects between economy and science offer a good platform to arouse interest of the farmers in the MRSA problem, as well as to inform the farmers

and enlighten them about dangers and connections. Interdisciplinary research in this area will contribute to a better understanding of the drug-resistance problem and to enhancing the realization of reducing the use of antibiotics on a long-term basis by farmers and veterinarians.

2.2 Introduction

Although originally only associated with medical institutions, the appearance of methicillin-resistant *Staphylococcus aureus* (MRSA) in other areas has been rising continuously. For the last few years the bacteria have been detected as livestock-associated MRSA (LA-MRSA) in pigs, cattle and poultry, as well as in animal keepers and veterinarians who are considered as an exposure risk group (Köck et al. 2011). The main focus lies with ST398, a clonal complex that is mutually transferable between livestock and humans (Köck et al. 2014). Potential risks of LA-MRSA have been discussed ever since. Against this background, pig-holding enterprises are the main focus of critical public reports, but the bacteria has been detected on dairy and cattle farms as well (Spohr et al. 2011).

In terms of research, the risks for humans and animals have been contemplated and evaluated by different disciplines (Schmithausen 2014). However, little is known about the perceptions of animal owners regarding LA-MRSA risks. This was the foundation for the two studies illustrated in the following discussion. These elicitations were performed to gather animal keepers' opinions under very different starting situations.

With the help of two sequentially performed studies, the following questions will be answered:

- What are the general perceptions and consciousness of farmers concerning the risk from drug-resistant bacterial problems?
- Do animal owners see their branch of profession and/or themselves as a risk regarding the spread of LA-MRSA outside the stables?
- Are there differences in risk perception and risk consciousness among animal owners regarding precautions that could be taken? What role does age or training play in this?
- To what extent have farmers changed their antibiotic usage with the increasing public discussions of the problem?
- What kind of connection does the participant's own colonization with MRSA have in the screening and frequency of animal contact?
- For which group of people does a particularly high risk of colonization exist?

The goal of both studies was to illuminate the unique dual role of farmers as a risk group due to their activity in animal stables on the one hand, and as decision makers with the responsible handling of antibiotics on the other hand. Owing to the realizations gained from these studies, concrete measures have been suggested on how risk awareness and sense of responsibility regarding the antibiotic problems can be further increased.

2.3 Materials and methods

For the two studies two different questionnaires were compiled for an interdisciplinary team of agronomists, human medical physicians, veterinarians, epidemiologists, and microbiologists.

For study I all 38 questions presented in Table 4 were entered into the program Unipark to create an online survey. In a pretest with three experts the conclusiveness of the questionnaire and the feasibility of the survey regarding time spent and how evaluable the results are, were verified and last changes were made. Finally, the questionnaire was enabled to active participation and the link to the survey was sent to three specialist web portals of federations and publishing houses, as well as to randomly selected farmers.

Subsequently, dividing lines, coordinates, and the four fields of a portfolio were defined in order to allow allocation of the respondents to four characteristic settings concerning risk perception and self-responsibility. The four characters were designated as follows:

- Risk oriented farmers
- Health oriented farmers
- Responsible, informed farmers
- Ignorant farmers

All questions of the questionnaire were selected that aimed at evaluating the participant’s risk perception and/or their degree of self-responsibility. The former contained questions about risk perception for livestock and consumers, risk estimation of contamination, opinion about personal risk of colonization, behavior in hospitals, and opinions on handling of antibiograms. The latter covered questions about the necessity of antibiograms, the comparison of antibiotic consumption to that of colleagues, the change in antibiotic consumption since 2006, an estimation of their own MRSA knowledge, and the execution of different hygiene measures inside and outside the stables. Depending on the answers each of the participants was assigned between 1 and 5 points per question, as represented in Table 2.1.

Table 2.1: Overview of the respective scaling

Score	Degree of risk consciousness	Degree of self-responsibility
1	Very low risk consciousness	Very low self-responsibility
2	Low risk consciousness	Low self-responsibility
3	Medium risk consciousness	Medium self-responsibility
4	High risk consciousness	High self-responsibility
5	Very high risk consciousness	Very high self-responsibility

From the individually reached scores, the determination of values for the degree of risk consciousness and self-responsibility was attained for each participant:

Degree of risk consciousness = $\frac{(X1+X2+\cdots+X5)}{5}$

Degree of self-responsibility = $\frac{(Z1+Z2+\cdots+Z28)}{28}$

Table 2.2: Overview of the questions included in the degree of risk consciousness

Variable	Question
X1	Risk perception for livestock and consumer (question No. 11)
X2	Estimation of the contamination risk (question No. 17)
X3	Estimation of the personal risk of colonization (question No. 18)
X4	Behavior in hospitals (question No. 23)
X5	Handling of antibiograms (question No. 24)

Table 2.3: Overview of the questions included into the degree of self-responsibility

Variable	Question
Z1	Necessity of antibiograms (question No. 24)
Z2	Comparison of antibiotic consumption among colleagues (question No. 25)
Z3	Change in antibiotic consumption since 2006 (question No. 26)
Z4	Estimation of their own MRSA knowledge (question No. 9)
	Performed measures before entering the stable (question No. 28)
Z5	Hand washing
Z6	Taking a shower
Z7	Changing clothes
	Performed measures after leaving the stable (question No. 29)
Z8	Hand washing
Z9	Taking a shower
Z10	Changing clothes
	Performed measures inside the stable (question No. 30)
Z11	Washing of stable
Z12	Cleaning and disinfection
Z13	Locks in stable

Variable	Question
Z14	Regulation of access for external people
Z15	Hygiene plan
Z16	All-in / all-out method
Z17	Wearing of gum shields
Z18	Air filters
Z19	Periodic animal examination
Z20	Isolation of diseased animals
Z21	Quarantine
	Performed measures outside the stable (question No. 31)
Z22	Employee training
Z23	Visitor books
Z24	Car locks
Z25	Veterinary hygiene consultation
Z26	Fencing
Z27	Black and white areas
Z28	Contact avoidance

Each pair of values corresponds to one spot in the portfolio. As a further form of depiction and visualization, bar charts and a Pareto diagram were selected. The inquiry of the second study took place during a producer communities' general assembly with 157 participants (see Table 2.5). In addition to questioning the participants via questionnaire, nose swabs were taken from the participants. The swabs were tested for MRSA by culturing with selective agars. The software package SPSS allowed statistical evaluation of the survey and measurement data. The results were visualized using bar charts.

The chi-square test and Fisher's exact test were used to determine statistical connections. In the context of the second study, the odds ratio was determined in addition to significance values. Information from both studies can be understood from Tables 2.4 to 2.6.

Table 2.4: Comparison of the different initial conditions concerning the organization of study I and study II

Criteria of the inquiry	**Study I** **Risk perception by sector**	**Study II** **Risk perception of selected groups**
Number of questions and question types	Total number of questions: 38 Closed questions: 36 of which single selection: 17 →including open answer: 1 of which multiple choice: 13 →including open answer: 13 of which matrix selection: 2 →including open answer: 2 Open questions: 2	Total number of questions: 14 Closed questions: 14 of which single selection: 13 →including open answer: 10 of which matrix selection: 1 Open questions: 0
Topic area of the survey	- General person and operating information - Used media for the acquisition of information - Estimation of personal MRSA knowledge - Personal risk estimation - Antibiotic use - Reduction possibilities of MRSA - Responsibilities within the MRSA area	- Personal animal contact - Hospital or retirement home stays - Professions of the participants' relatives in health service - Antibiotic therapies in the last 6 months - Appearance of badly healing wounds - Previously known MRSA contaminations
Multiplier	- Web portals of agricultural journals - Forwarding of the survey to randomly select-ed farmers	General assembly of a producer group, as well as participation in a joint project
Style of survey	Anonymous	Personal questioning and personal integra-tion into a research project
Feedback opportunity	Free input option at the end of the question-naire	Possibility of direct personal exchange, as well as telephonic queries

Table 2.5: Overview of gross and net participation of participants in studies I and II

Overview of the participation		
	Study I	**Study II**
Gross participation	**100.0% (249)**	**100.0% (157)**
Net participation	**75.5% (188)**	**100.0% (157)**
Of which sorted out due to substantial num-ber of questions not answered and/or skipped	27.7% (69)	
Of which sorted out due to irrelevance of vocational fields (veterinary surgeons, poul-try owner)	7.2% (18)	
Evaluable participation	**40.6% (101**) of which were: pig owners: 54.5% (55) cattle owners: 43.6% (44) cattle and pig owners: 1.9% (2)	**100.0% (157)** of which were: farmers: 62.4% (98) veterinarians: 7.0% (11) other (consultants, etc.): 29.3% (46) no answer: 1.3% (2)

Table 2.6: *Overview of criteria for participant categorization and amount of usable answers in study I*

Criteria for categorization of the participants	Scaling of answers	% (absolute)
Age (question No. 2)	under 25 25 to 55 over 55	9.9% (10) 74.3% (75) 15.8% (16)
Professional training (question No. 5)	University degree Apprenticeship in agriculture Apprenticeship in other areas No apprenticeship	26.7% (27) 65.3% (67) 5.0% (5) 3.0% (3)
MRSA findings (question No. 19)	Positive Negative	31.7% (32) 68.3% (69)
Risk perception (question No. 11)	Very high High Low Very low No risk at all	5.9% (6) 62.4% (63) 25.7% (26) 1.0% (1) 5.0% (5)
Antibiotic consumption since 2006 (question No. 26)	More Equal Less Much less Not answered	2.0% (2) 70.3% (71) 17.8% (18) 6.9% (7) 3.0% (3)
Farmer as risk group? (question No. 18)	Yes No	33.7% (34) 66.3% (67)
Aversion of physician to agricultural background (question No. 23)	Yes Not always Only when specifically asked No	32.7% (33) 16.8% (17) 44.6% (45) 5.9% (6)
Information demands for risk estimation (question No. 13)	Yes No	52.5% (53) 47.5% (48)
Information demands for risk reduction (question No. 14)	Yes No Not answered	47.5% (48) 50.5% (51) 2.0% (2)

Table 2.7: Overview of criteria for the subject's categorization and amount of usable answers in study II

Criteria for categorization of the participants	Scaling of answers	% (absolute)
Participant's animal contact (question No. 1.1)	Direct animal contact	94.9% (149)
	→of which tested positive for MRSA	50.3% (75)
	→of which tested negative for MRSA	49.7% (74)
	No direct animal contact	5.1% (8)
	→of which tested positive for MRSA	12.5% (1)
	→of which tested negative for MRSA	87.5% (7)
	Total	100.0% (157)
	→of which tested positive for MRSA	48.4% (76)
	→of which tested negative for MRSA	51.6% (81)
Frequency of contact of the participants (question No. 1.2)	Daily animal contact	85.9% (122)
	→of which tested positive for MRSA	56.6% (69)
	→of which tested negative for MRSA	43.4% (53)
	Animal contact every other day	1.4% (2)
	→of which tested positive for MRSA	0.0% (0)
	→of which tested negative for MRSA	100.0% (2)
	Weekly animal contact	7.7% (11)
	→of which tested positive for MRSA	18.2% (2)
	→of which tested negative for MRSA	81.8% (9)
	Animal contact every two weeks	1.4% (2)
	→of which tested positive for MRSA	50.0% (1)
	→of which tested negative for MRSA	50.0% (1)
	Animal contact once a month	2.1% (3)
	→of which tested positive for MRSA	0.0% (0)
	→of which tested negative for MRSA	100.0% (3)
	Animal contact rarer than once a	1.4% (2)
	month	0.0% (0)
	→of which tested positive for MRSA	100.0% (2)
	→of which tested negative for MRSA	
	Total	100.0% (142)
	→of which tested positive for MRSA	5.7% (72)
	→of which tested negative for MRSA	49.3% (70)

2.4 Results

The participant's age is a factor on which risk perception—which can spring from MRSA—is dependent. Figure 2.1 shows the frequency distribution relevant to the five scale stages of low to very high risk, which is regarded differently in the three age groups. The three age groups are specified on the x-axis. The y-axis clarifies the proportional distributions of the different perceptions of the animal owners concerning the MRSA risk.

Figure 2.1 shows that in all three age groups most participants estimate the risk as high. The older the participant, the smaller the number of animal owners who perceive the risk as high. While 80.0% of the participants younger than 25 indicate a high MRSA risk, 66.7% of the participants between 25 and 55 do so. The number of participants who estimate the risk as low amount to 20.0% (under 25), while 33.3% in the middle aged (25–55 years) group also estimate the risk as low.

However, it is noticeable that the number of participants with a high perception of risk increases (68.8%) in the group of participants older than 55 years.

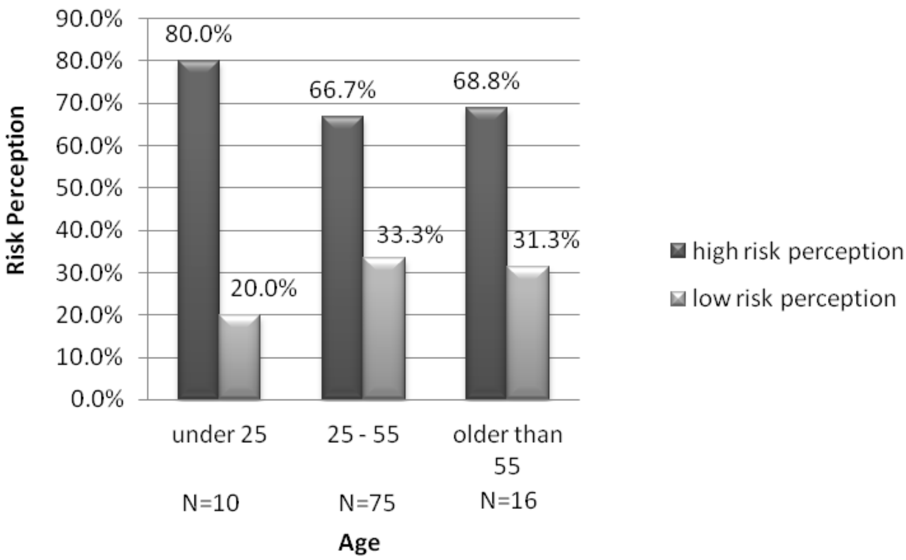


Figure 2.1: Influence of age on risk perception of the participants (p=0.695)

Three groups are formed according to the education level of the participants. Figure 2.2 shows that classification of the MRSA risk turns out differently depending on the participant's education level. The degree of training of the participants is represented on the x-axis. The y-axis represents the proportional distribution of the selected answers.

Figure 2.2 illustrates that people with a high educational level are inclined to see a higher risk. While 62.0% of the farmers with a practical, vocational training consider the risk as high, 66.7% of participants with a university degree also do so. Only 33.3% of animal owners without any training see this likewise. A very high risk perception is indicated by 5.6% of trained participants, while 7.4% of farmers with academic training selected the same answer. Even though the group of participants without training is extremely small (three people), it is noticeable that none of them detect a high risk.
The perception of a low MRSA risk can be seen in over a quarter (28.2%) of animal owners with vocational training. It is slightly smaller (22.2%) in farmers with university degrees. None of them marked on the answer scale that there would be no risk.

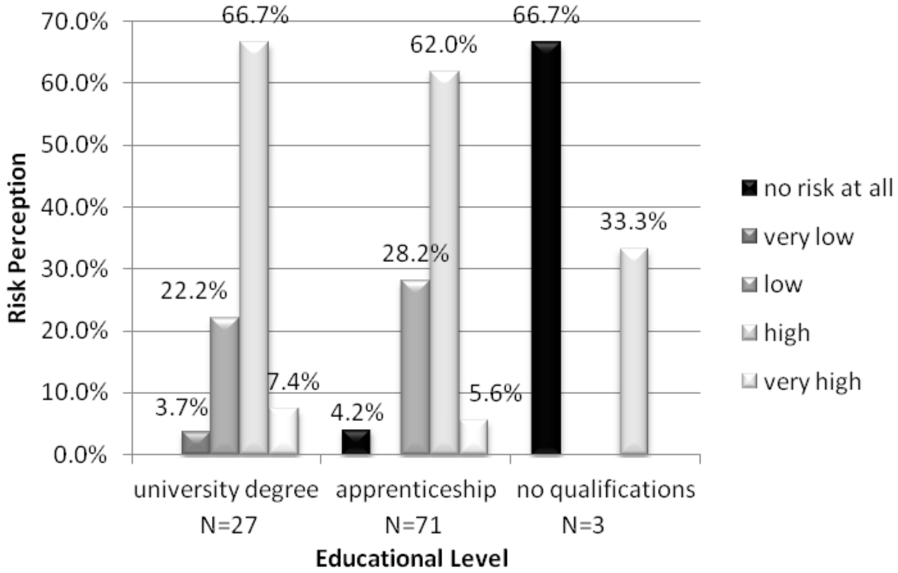


Figure 2.2: Relationship between education level and amount of answers related to the five stages of risk perception (p=0.042)

Concerning the question regarding the existence of MRSA colonization in people and their respective families, 32 participants answered "yes." It is clear from Figure 2.3 that the circle of affected persons differs percentage-wise when the type of animals being held are considered. While only 9.1% of cattle owners acknowledge positive MRSA findings within their families, nearly half of the pig owners respond similarly.

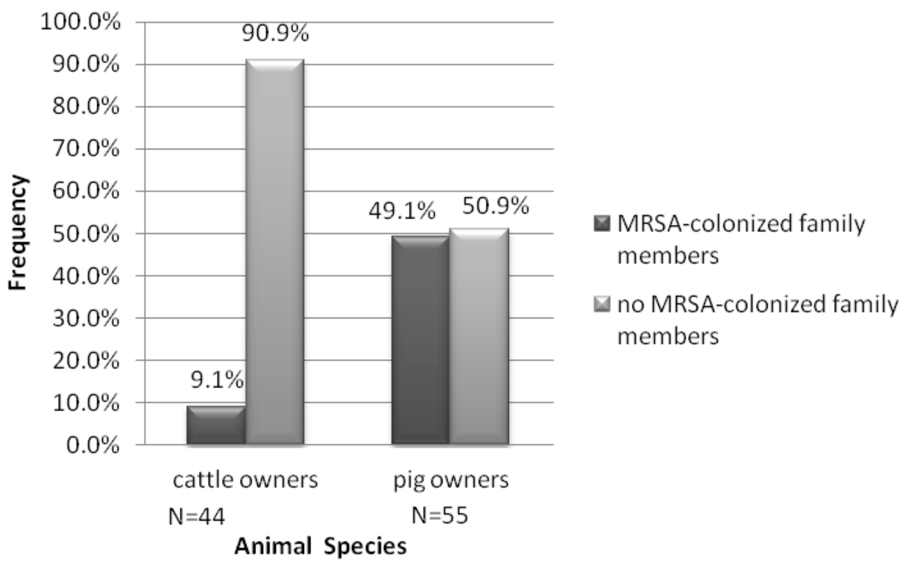


Figure 2.3: Animal species-referred relative and absolute number of positive answers about colonized family members (p=0.000)

Groups with colonized family members answered differently compared to the group of participants with no affected family members. In Figure 2.4 it is noticeable that participants with MRSA-positive incidents within their family state a high risk more often (68.8%) than farmers without MRSA-positive cases (59.4%). Nevertheless, 8.7% of animal owners without positive MRSA findings in their family estimate the MRSA risk as very high, while nobody within the group of affected relatives indicates the same.

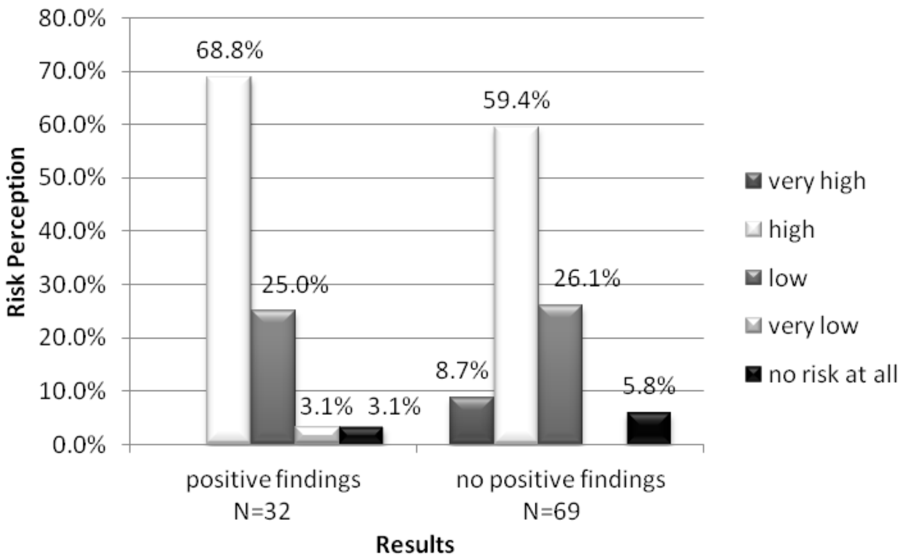


Figure 2.4: Percentage of answers to the five-step risk scaling in the group of participants with family members and participants without respective known findings (p=0.247)

When comparing the answers of both groups with regard to their changed antibiotic use (Figure 2.5), it is clear that there is a trend between antibiotic use and participants' risk estimations. Taken together, a collectively high risk estimation becomes clear. It increases from 65.8% in participants with equal or higher antibiotic consumption compared to 76.0% in participants with lower or much lower consumption.

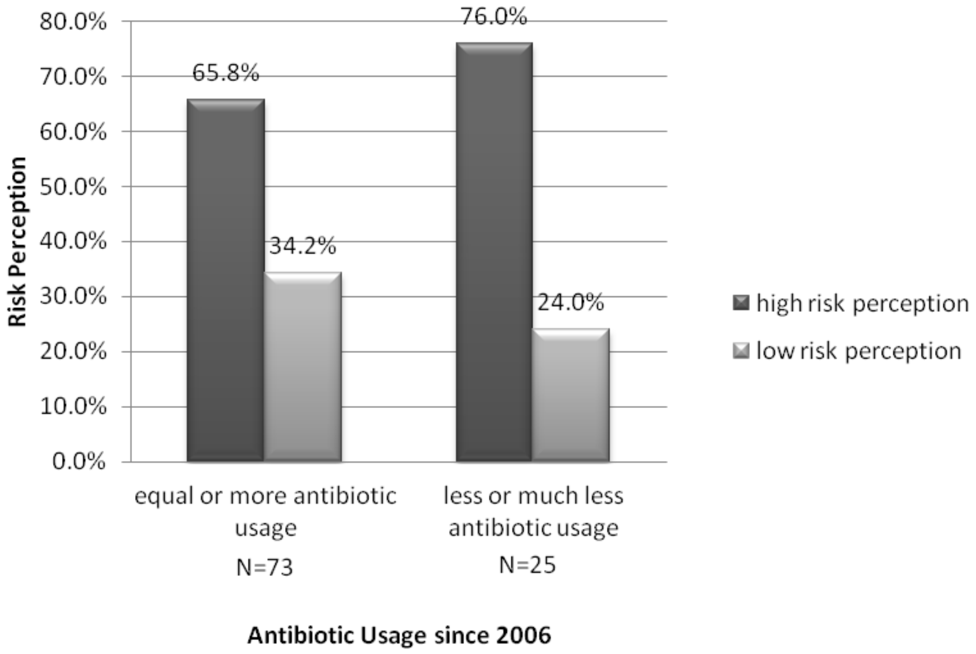


Figure 2.5: Proportional amount of answers to the five-step scaling of antibiotic use (p=0.342)

Figure 2.6 clarifies the participants' opinions concerning their position as a risk group within the MRSA problem. Moreover, the participants' opinions are shown divided by animal species. While only 22.7% of cattle owners see themselves as members of a risk group, 41.8% of pig owners share the same opinion. The majority of cattle owners (77.3%) and a smaller majority of pig owners (58.2%) have a different opinion. This connection is significant.

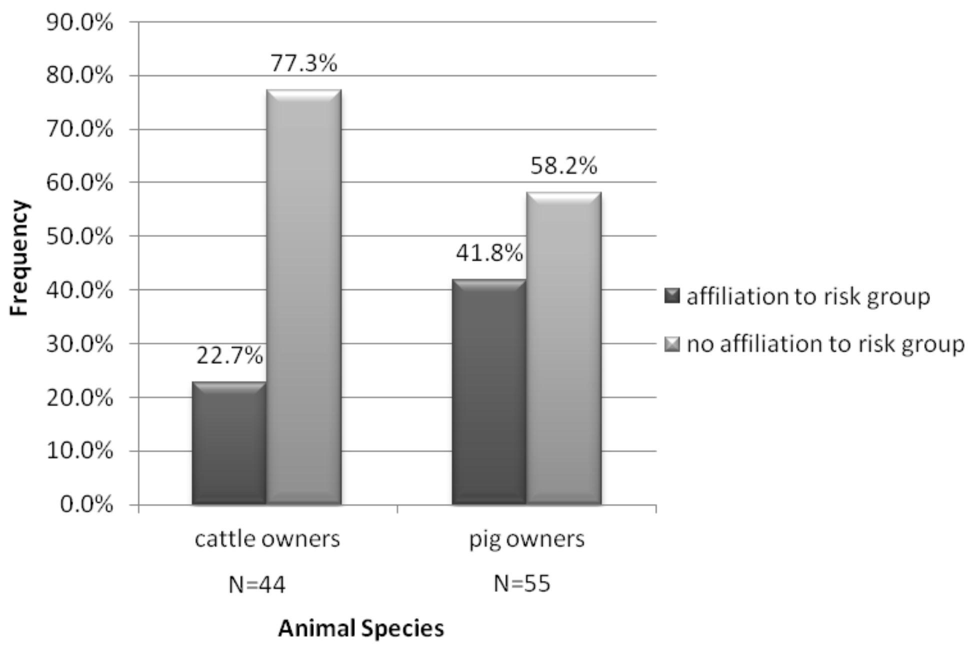


Figure 2.6: The percentage of answers to the question of self-classification concerning the affiliation to an MRSA risk group of cattle owners compared to pig owners (p=0.045)

Figure 2.7 advises about the animal owners' information needs. The largest information demand is in the area of potential reduction measures for the MRSA risk (63.4%). Approximately half of the participants indicated a need for information about estimation measures on their farms. Little information is needed in the field of monitoring (21.8%).

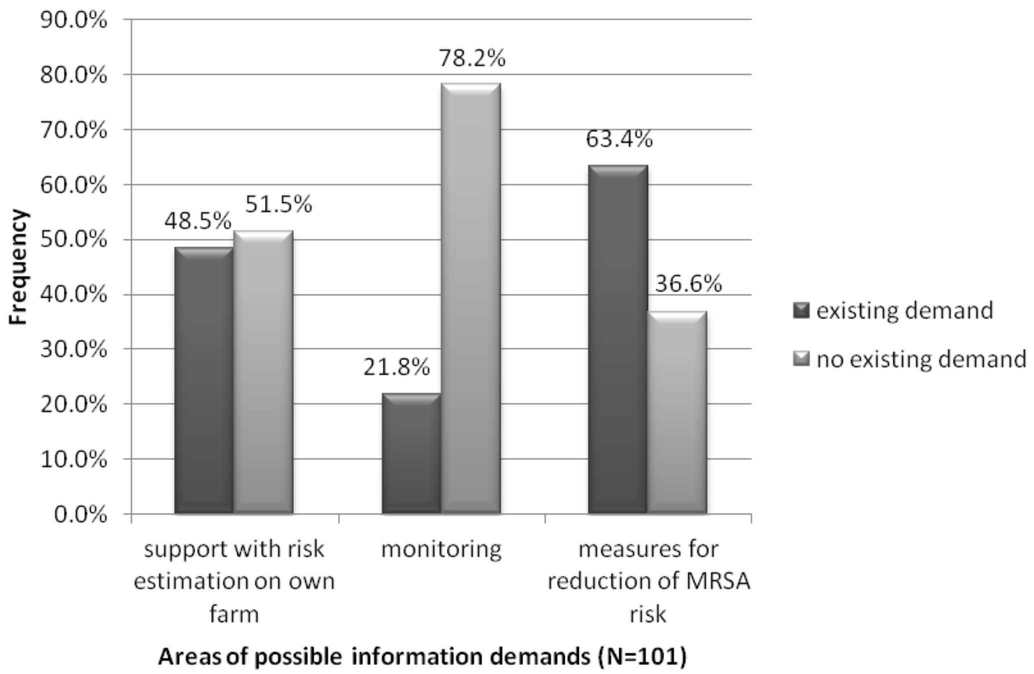


Figure 2.7: Areas of information demands

The farmers' estimates about potential risk areas in the stable are represented in Figure 2.8. The most highly estimated risk potential is in the area of animal purchase (68.8%), followed by the animal's health status (60.4%). The excessive use of antibiotics (55.4%) and the presence of chronic illnesses within the herd (52.5%) are also stated as potential risk areas by the majority of participants. However, parameters such as herd size (17.8%), overcrowding (28.7%), and contaminated feed (24.8%) are mostly not estimated as risk areas.

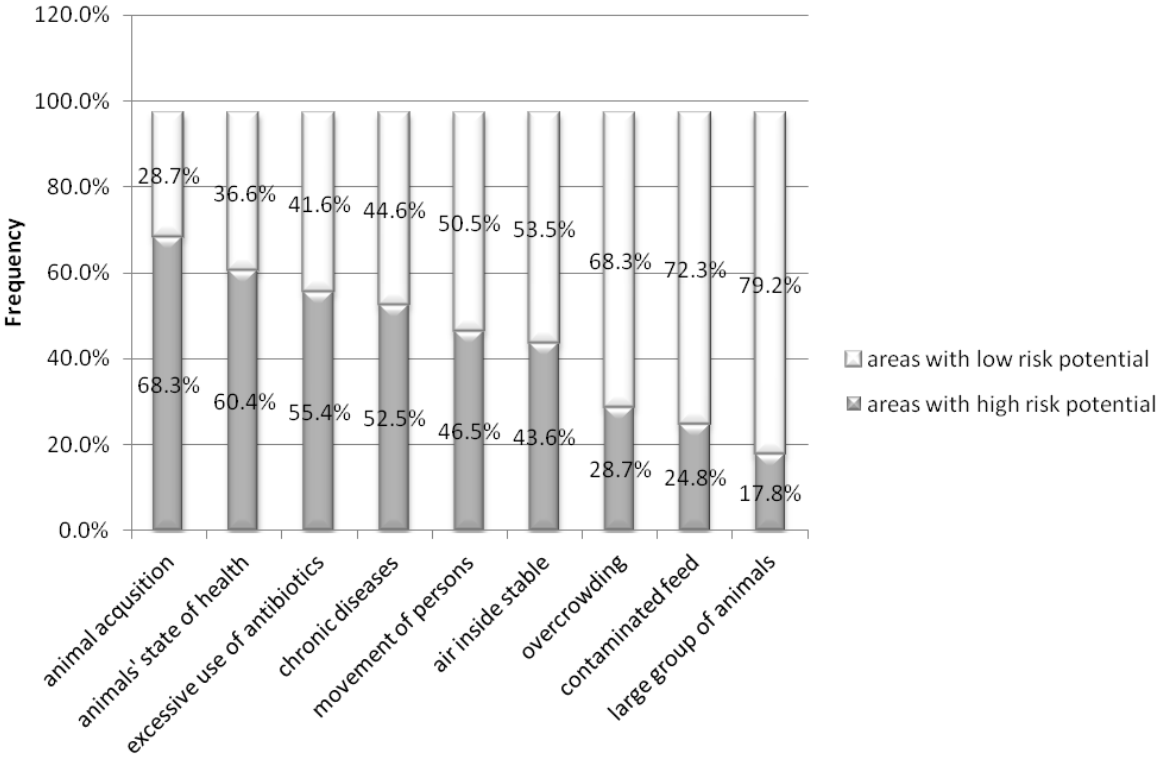


Figure 2.8: Estimates regarding potential risk areas within the stable

Figure 2.9 illustrates the classification of the participants depending on the degree of their respective risk perception, as well as their respective sense of responsibility. Based on how 101 test people responded to the questions, an estimate was made concerning the risk related to the answers of the questions and the participants were assigned to determined characters in the contingency table. Only 15 participants lie in the quadrant in the bottom left hand corner, which is labelled "ignorant." The participants assigned to this field are characterized by a small degree of self-responsibility and risk perception, while the group assigned to the quadrant in the upper right hand corner are both health and risk oriented. The participants within the other two groups tend to lean either toward a high level of self-responsibility—and are, therefore, classified as health oriented—or toward a high level of risk perception.

As seen in the four-field matrix, the largest portions of participants are either located in the group of "risk-oriented" farmers or connected to the group of "responsible and informed" farmers.

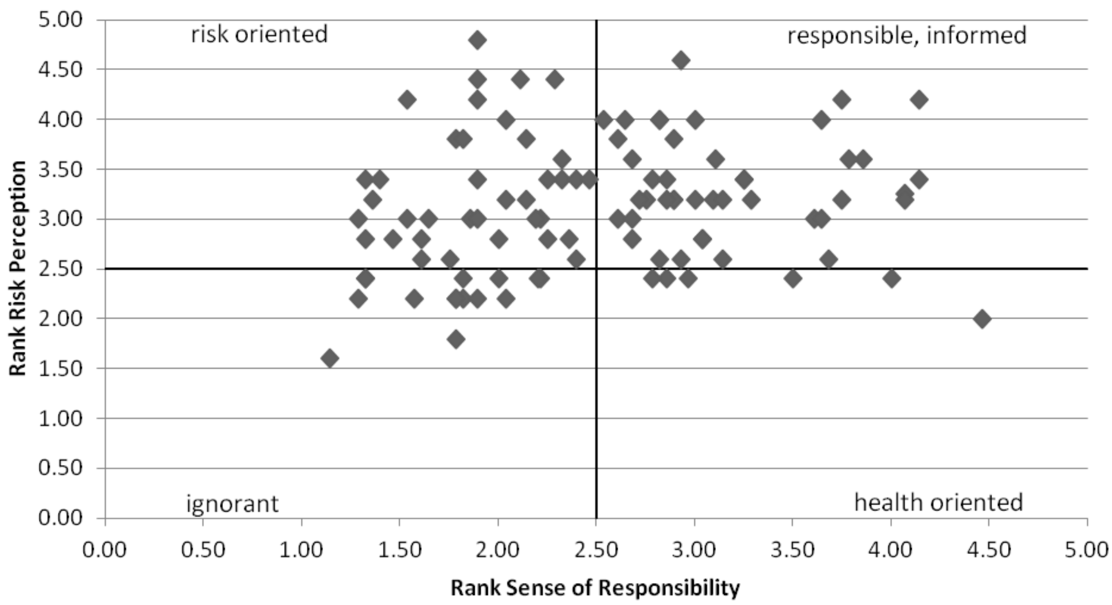


Figure 2.9: Classification of farmers depending on risk perception and sense of responsibility (N=101)

For the participants of the second study who took part in both the survey and the screening for colonization risk, 87.5% without direct animal contact tested negative for MRSA. Half of the participants with animal contact show MRSA colonization.

The risk of colonization seems to depend on how regularly contact is made with animals and stable air. Comparing the two groups—those with daily contact and those with less than daily animal contact—56.6% of participants with daily contact are colonized with MRSA, while only 15.0% of the participants who stated less frequent animal contact received the same results (Figure 2.10).

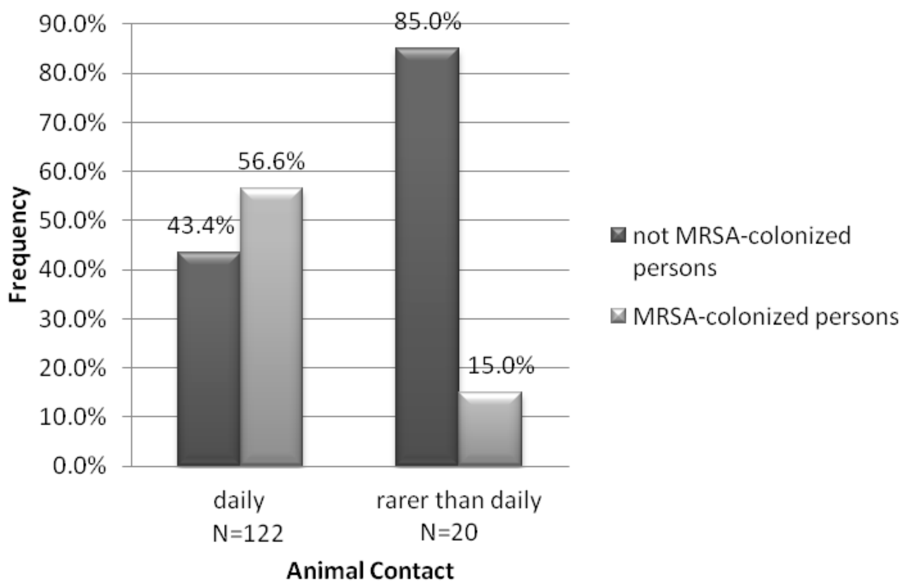


Figure 2.10: Percentage frequency of colonized and non-colonized participants with daily and irregular animal contact (p=0.001)

Several occupational groups participated in the study's screening examinations (see Table 2.5): Farmers, veterinarians, and people with professions without intended animal contact. In Figure 2.11 the three groups are compared with regard to the risk of MRSA colonization.

As expected, farmers are more frequently colonized than veterinarians or other occupational groups; 66.3% of farmers who took part in the screening show a positive MRSA result. Half of the tested veterinarians are colonized, while only 13.0% of people of other occupational groups show a positive test result (Figure 2.11).

Calculating the odds ratio the risk for animal owners and veterinarians to become colonized through their daily work in the stable is 11.9. Despite the small number of people who did not have daily animal contact, the determined differences are statistically protectable.

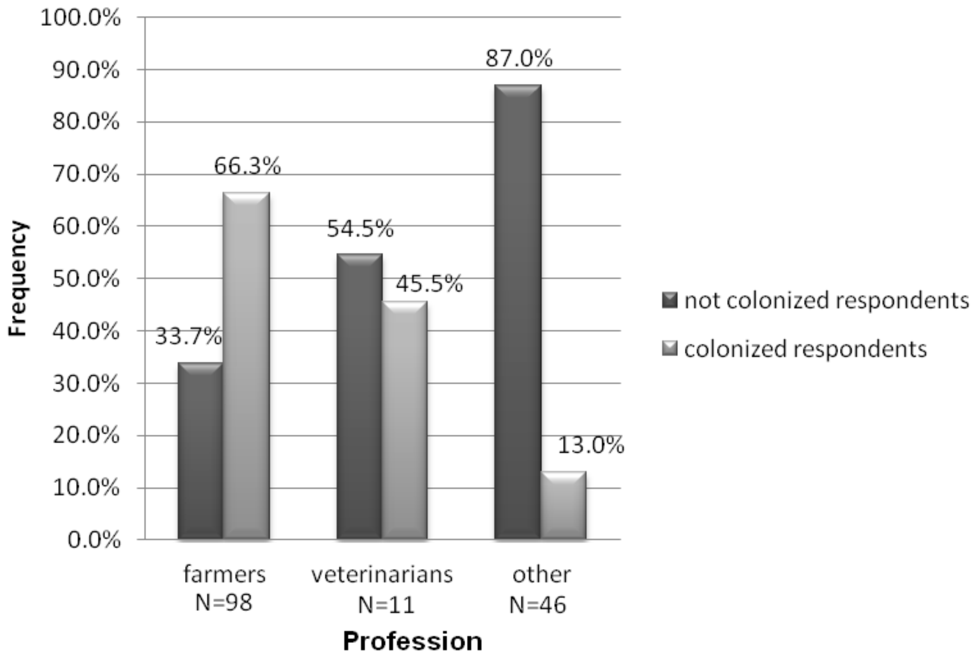


Figure 2.11: Connection between occupational group and laboratory findings (p=0.000)

2.5 Discussion

For the first time about 400 people—who actively wanted to partake in scientific studies for the estimation of MRSA risks—were available for empirical studies and screening examinations: persons active in agricultural animal-holding enterprises, veterinarians, agricultural advisors, and animal owners and their respective families. Within this circle of people, evident and partly statistically securable differences in risk estimation, as well as in the animal owners' behavior concerning the handling of antibiotics, are clearly recognizable.

People between 25 and 55 years—thus, within an age section in which farmers have the main responsibility for their enterprise—appreciate less often the risk of becoming colonized by their behavior in their daily workflow than younger or older people. A reason for this could be that people in this age group are bent on classifying their working sphere, which can be shaped by themselves as safe, whereas young farmers (pre-acquisition) are usually still in training and, therefore, learn a lot more about possible backgrounds and connections of risks of antibiotic usage for themselves and family members than previous generations. Also, the factor of keeping oneself updated about the current status of discussions concerning multi-resistant microorganisms in animals and humans has to be taken into consideration. Animal owners work on average up to 50 to 60 hours per week on their farms (agrarheute.com 2012). After the successor's acquisition of the enterprise, the farmer has more time than before to inform himself; alternatively, the farmer encounters this problem due to more frequent hospital stays, which occurs within this age group. Hence, many hospitals classify farmers as a risk group (BfR 2009) and perform respective examinations prior to surgeries. In Germany only 0.6% of farmers are under 25 years old; 67.6% are between 25 and 55 years and 31.8% are over 55 years (Statistisches Bundesamt 2010). In the self-sample 9.9% of the survey participants were under 25 years, 74.3% of participants were between 25 and 55 years and only 15.8% were older than 55 years.

The degree of vocational training has a clear influence about how a possible risk is perceived. Farmers with academic training evaluate some risks differently than farmers with occupational training. Within the frame of university education, man-animal-environment interactions are often put into a superordinate context and impulses for self-reliant acting are given. The national average for the relative amount of farmers with academic training is 19.5%, while the national average of farmers with complete vocational training is 80.5% (Statistisches Bundesamt 2010).

From those who took part in the study represented here, more than a quarter were university graduates (26.7%); the amount of farmers with vocational training was 70.3%. Only a few participants indicated they did not have any vocational training. There is a connection between the change in behavior of antibiotic usage since 2006 and the way resistance risk is classified. Farmers who view their antibiotic usage since 2006 as unchanged stated less often a high perception of risk, since they did not assume a connection with the resistance. However, farmers who reduced their antibiotic usage consistently estimated the risk for themselves, their family, and their livestock as high. Over 70% of the participants—and, therefore, by far the largest portion of animal owners—indicated that they maintained their antibiotic consumption. A quarter, however, could reduce the quantity of antibiotics used since 2006. From the data published by BUND in Fleischatlas 2013, it becomes clear that there has been no obvious decrease in the quantity of antibiotics used in the area of veterinary medicine in Germany since 2006 (BUND 2013). The data from the GERMAP reports of the Bundesamt für Verbraucherschutz und Lebensmittelsicherheit even show a rise in antibiotic consumption from 784.4 t in 2005 to 1826.0 t in 2012 (BVL 2008, BVL 2012). This also shows that in the broad mass of animal owners the connection between high antibiotic use and its consequences has not yet been sufficiently recognized. On the other hand, the participants of the current study seem to be a sample of farmers particularly receptive towards the topic and who are interested in the different opinions. The occurrence of MRSA-positive results in the questioned farmers or within their closest family circle did not seem to influence their answers to questions about measures to protect themselves from colonization. It is already known from other studies that the prevalence of MRSA in pig owners is 86.0%, and in cattle owners it is 77.7% (Köck et al. 2011, Spohr et al. 2011). Therefore, these occupational groups are seen as risk groups. Only a third of the participants in the online survey (31.7% study I) or one of their family members reported being infected at least once by MRSA.

Apart from answers to the questions, further realizations from the survey can be obtained. Many farmers feel that they have been wrongfully cast by negative media. A number of the participants used the opportunity of free expression at the end of the questionnaire—eventually all addressed the same problem, that of bad media representation of farmers. Many animal owners feel wrongfully accused of being mainly responsible for the complex MRSA problems in the health care sector. They wish for more differentiated media clarification for the public.

The fact that 157 participants were content to get themselves tested—whether they were colonized with MRSA or not—shows their interest in actively participating in solving the problems. However, they are also particularly interested in experiencing more about their vocational risk.

With the question of whether direct animal contact leads to an increased MRSA rate, Cuny and co-authors (2009) also performed screenings. The vocational contact with MRSA-positive pigs and the risk of being colonized is around 138 times higher than for non-exposed people. Wissmann and co-authors (2011) confirm that farmers and veterinarians are colonized with MRSA more frequently than other occupational groups. In a statement by the BfR (2009), it is recommended to assign people with frequent animal contact to a risk group. In the study presented here it is determined that it is not the animal contact itself, but the regularity of stable visits that is responsible for the colonization risk. The risk for people with daily animal contact is significantly higher than for people who are only irregularly active in stables. Farmers, therefore, are at particular risk of becoming MRSA carriers compared to relatives with other professions or advisors. The odds ratio, which is the risk for animal owners and veterinarians to become colonized through their daily work inside stables, is 11.9. Veterinarians, at least within the participant sample, who are in stables just as frequently as farmers seem to have prevented colonization due to their consideration of special hygiene measures, such as wearing gloves and gum shields.

From the portfolio figure (Figure 2.9), as a possibility of the recapitulatory characterization of this study's participants, it is clear that most people who took part have good advance information and a high sense of self-responsibility. Compound projects between animal owners, producer communities, and scientists offer the advantage of initiating the willingness to reconsider longstanding behaviors of handling antibiotics over personal contacts.

Also, understanding the implementation of MRSA and ESBL monitoring in livestock is a subsequent reaction (Schmithausen 2015). Thereby, the personal risk, as well as the transmission risk between humans and animals for MRSA, can be measured. Examples show that if farmers are completely aware of their own situation and have understood the connections within the multi-resistance dynamics, they are also willing to make changes (Schmithausen 2015).

3 Comparing Structure Analysis to characterize typical complex causes for anomalous behavior (such as pig tail biting) in different husbandry and management systems

This article has been published in German:

SOPHIA SCHULZE-GEISTHÖVEL[1], THORSTEN KLAUKE[1], FRIEDHELM JAEGER[2], MARTIN HAMER[3] AND BRIGITTE PETERSEN[1] (2012)

Vergleichende Strukturanalysen zur Charakterisierung von typischen Ursachenkomplexen für Verhaltensanomalie wie Schwanzbeißen beim Schwein innerhalb unterschiedlicher Haltungs- und Managementsystemen.

In: Nutztierpraxis aktuell, Vol.41 S. 12-17

[1] Institut für Tierwissenschaften, Rheinische Friedrich-Wilhelms-Universität Bonn, Katzenburgweg 7-9, D-53115 Bonn

[2] Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen, Schwannstraße 3, D-40476 Düsseldorf

[3] GIQS e.V., c/o Universität Bonn, Katzenburgweg 7-9, D-53115 Bonn

*Corresponding author: Sophia V. Schulze-Geisthövel.
Email: s.schulze-geisthoevel@uni-bonn.de

3.1 Abstract

In Europe, as in all countries with intensive pig production, there is currently a discussion about how the shortening of tails of piglets that are only a few days old, which is a routine procedure, can be given up. In contrast to the European pig farmer, only a small number of farmers in China take this measure. The objective of this study was to find out which factors are crucial to the Chinese pig farmers for shortening piglet tails, especially when it is not economically reasonable. Furthermore, it was also of interest to determine which preventive measures the farmers take who still disclaim cutting. While it was not the aim to test how possible it would be to transfer Chinese farming structures to conditions in European pig production, it was the aim to characterize the different approaches to the problems of tail biting and cannibalism.

3.2 Introduction

In Europe possible reasons for heaped appearance of tail biting includes changed life and husbandry conditions with little stimulus over the years (Strafford 2010). There is agreement that tail biting is an indicator of a multifactorial problem and is, therefore, often released by a batch of risk factors. The combination of reasons can be different from farm to farm (Knoop 2010, EFSA 2007). The risk of tail biting is increased by a number of stressors, including **mistakes in feeding** (Hunter et al. 2001; Schrøder–Petersen and Simonsen 2001; Tailor et al. 2010), **damaged floor and components that are against animal welfare** (Hunter et al. 2001; Prange 2004; van de Weerd 2005; van de Weerd et al. 2005), **little space** (Schrøder–Petersen and Simonsen 2001, Roth and Meyer 2002; Moinard 2003; Schmolke et al. 2003; Prange 2004; EFSA 2007; Knoop 2010), **inadequate hygiene and health management** (Schrøder–Petersen and Simonsen 2001; Widowski 2002; Moinard 2003; Jensen et al. 2004; Walker and Bilkei 2006; Kritas and Morrison 2007;Salmano et al. 2008; Tölle 2009; Taylor et al. 2010), and an **inadequate production process** from birth until the end of fattening (Moinard 2003, Breuer 2005, van de Weerd 2005, EFSA 2007). Taylor and co-writers (2010) distinguish three different stages of tail biting. The two-stage, sudden-forceful, and obsessive stage. These forms were, in the opinion of the authors, triggered by other reasons. They observed most often the damaging stage of the two-stage type and the sudden-forceful type. Compared to this, Walker and Bilkei conducted a distribution of the intensity level (tail biting score, TB), from the lowest form, which is tail chewing (0), through to inflammation of the tail area with strong swelling until total loss of the tail (4). The group "0" means that there is no evidence of tail biting (Walker and Bilkei 2006). Pütz et al. (2011) distinguish two forms of cannibalism on the basis of their physiological-ethological explanatory model.

The authors note primary cannibalism as being triggered by lack of socialization—that is, through a short suckling period, motherless rearing—but also through a genetic disposition for low stress tolerance. The outcome is a display of aggressive behavior by animals toward one another and a behavioral abnormity under special stress situations. With primary cannibalism the whole tail gets gnawed, not only the tag. Secondary cannibalism, as viewed by the authors, is expression of an overstrained physiological ability of the pigs to adapt. Gastrointestinal health and a lack of feeling of satiety are often discussed as triggers (Pütz et al. 2011).

3.3 Material and methods

The study is, as shown in Figure 1, partitioned into three phases that build on each other with five substeps and three partial results. This article is limited to the partial results pledged in grey. In preparation for the empirical study in China, two literature studies took place during a six-month analysis phase, out of which the criteria and

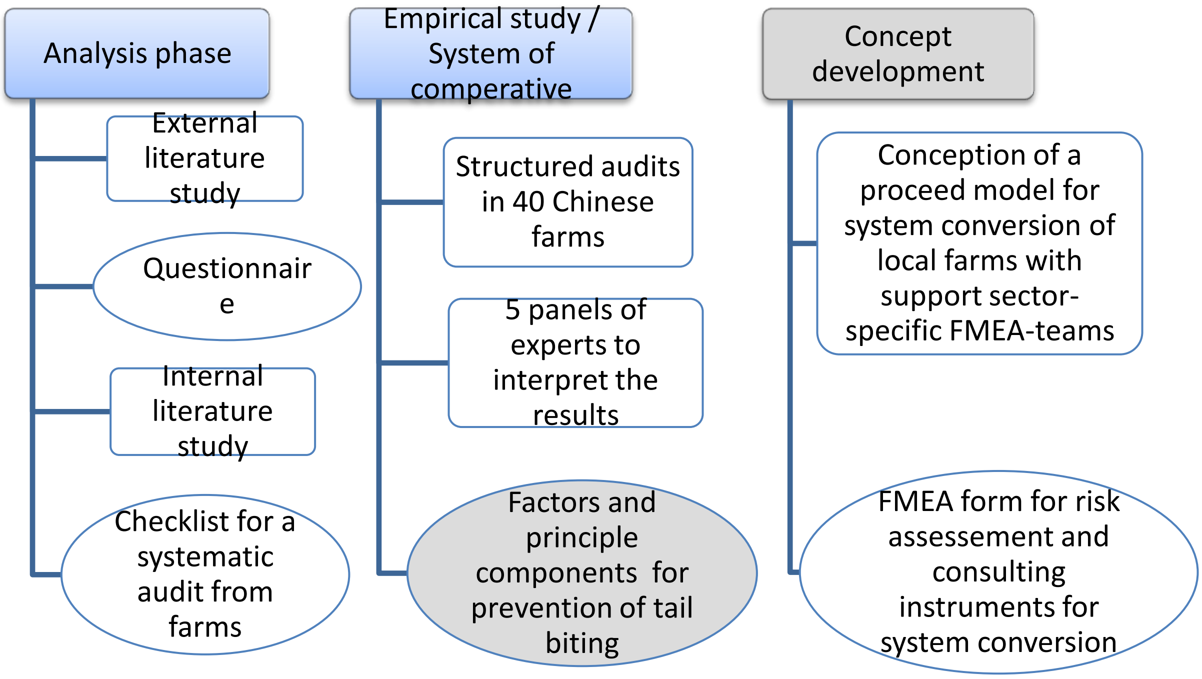


Figure 3.1: Phases, some steps, and the results from the experimental study

approaches for the structured audits were derived. The farms were analyzed between February 2011 and May 2011 in the province Sichuan, People's Republic of China. During this time 40 Chinese pig farms were visited. Of these farms, 20 kept pigs with cut tails and the other half kept pigs without cut tails. The superintendent survey and the onsite audit took place in the form of a structured questionnaire and a checklist, in which 60 aspects were addressed. On each farm a stall survey was conducted for several hours. Dates, facts, and estimates from the following themes were recorded: Operational indicators, management, stall climate, employment materials, and feeding. The onsite audit was divided in two parts: As a first sample the pigs and their behavior towards one another was measured, followed by a monitoring of the working methods of the personnel/staff. Furthermore, photos were taken on each farm for later documentation and evaluation. Statistical evaluation of the questionnaires were performed with the statistics program SPSS. Data was processed and the graphical representations were made with this program. Nine data-related single aspects were grouped into four index values, with which intensity and extensity steps were characterized and represented within a portfolio: Care and employment intensity, growth and housing extensity. These four index values were calculated depending on the parameters from measured and estimated data for each of the farms (see Table 3.1).

Table 3.1: Survey of the index parameters and categories of the parameter values, as well as the factors and main components

Index parameters	Categories of the parameter values	Factors F 1-4	Main components H1,2
Feeding technologies (a)	cross trough = 10 trough in-line = 10 Dry feeder = 0 Wet feeder = 0 Floor = 5	F1 Care intensity = (a+b+c) / 3	H1 Variety
Feeding regime (b)	Rationed = 10 Day rationed = 5 Ad libitum = 0		
Ground texture (c)	Fully slatted floor= 0 Partially slatted floor = 0 Organic material = 10 Flatted floor = 10		
Manipulable materials (d)	Yes = 10 No = 0	F2 Activity intensity = (d+e) /2	
Type of food (e)	With vegetables = 10 Without vegetables = 0		
Daily growth (kg) (f)	0.571–0.86 = 10 0.87–1.149 = 5 1.15–1.5 = 0	F3 Growth extensity = f	H2 Production extensity
Range of place in m² (g)	0–0.6 = 0 0.7–1.4 = 5 >1.5 = 10	F4 Housing extensity = (g+h+i) / 3	
Fresh air supply (h)	Artificial ventilation = 0 Natural ventilation = 10		
Group size (i)	> 20 pigs/pen = 0 0–20 pigs/pen = 10		
10 = very good 5 = moderately 0 = bad			

A portfolio showing the relationship of care and employment intensity, and a portfolio showing the relationship between the factors of growth and maintenance extensity were created. The following hypotheses were behind these portfolios.

H1: The higher the care and employment intensity on a pig farm, the lower is the risk potential that tail biting becomes a problem.

H2: With sufficient care intensity, a lack of employment can be compensated for and vice versa.

H3: The more extensive the attitude conditions and the animals growing in a pig farm, the lower is the risk potential that tail biting becomes a problem.

H4: With sufficient housing extensity a low growth extensity can be compensated and vice versa.

The scale of both portfolios range from zero to ten, in which zero describes a very high risk for tail biting and ten a very low risk. Furthermore, a principal-component analysis was performed. The two main components of the explanation of the determined variances were derived by compacting the data and then calculating data from the operation factors. These two main components show the influence of the four factors of housing and growth extensity and care and employment intensity on each other and on the single farms.

3.4 Results

Considering the indicators characterizing the housing conditions on farms where pigs' tails are cut and uncut, there are no statistically significant differences.

Figure 3.2 shows a portfolio with four quadrants in what the calculated index values of the farm for the care and employment intensity are registered.

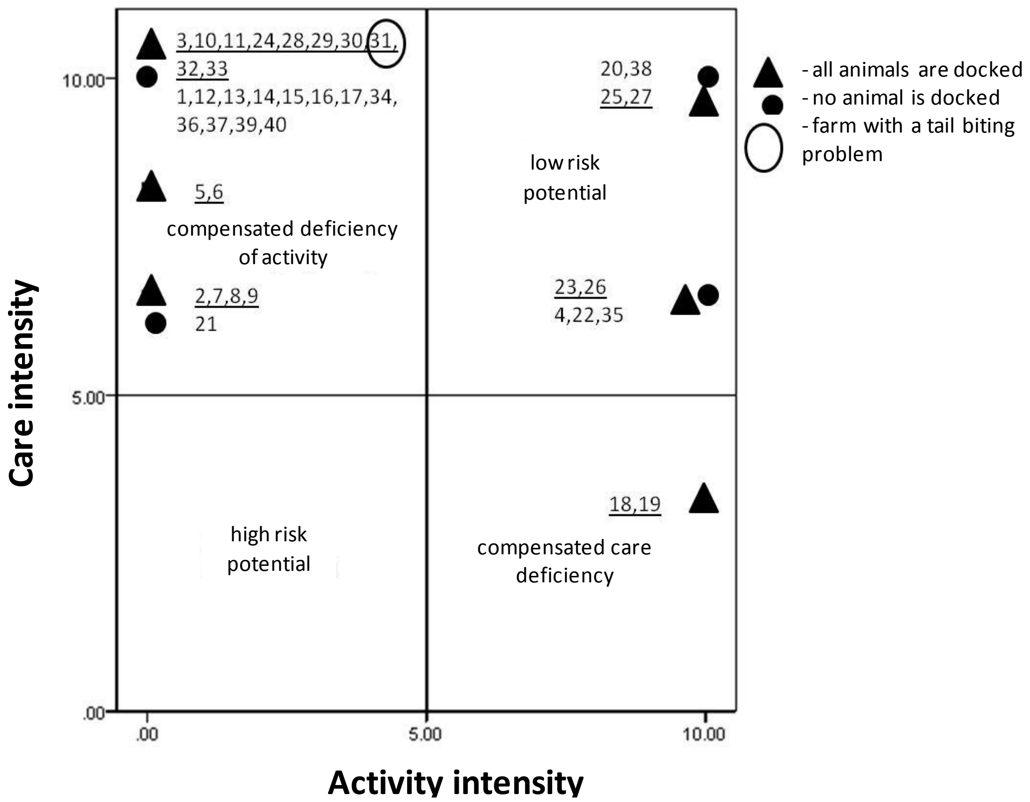


Figure 3.2: Portfolio for the relationship of care and activity intensity

The numbers from one to 40 represent the ongoing operation number. Farms on which pigs have cut tails are marked with a triangle; farms where the pig tails are not cut are marked with a circle. The lower left quadrant is marked with the designation “high risk potential” and has no farm numbers. The lower right quadrant has the designation “compensated care deficiency” and has only two farm numbers. The calculation values for most of the farms are in the upper left quadrant, which is designated “compensated deficiency of activity.” Also included in this quadrant is farm number 31 where tail biting was observed during the audit. Characteristic values from nine farms are in the upper right quadrant, in which both the care intensity and activity intensity are very high. This quadrant is, therefore, marked with the designation “low risk potential.”

Considering the portfolio (Figure 3.3) where alignment of the 40 farms with respect to the criteria of growing and housing extensity, there is a considerably different picture for assignment to the four quadrants.

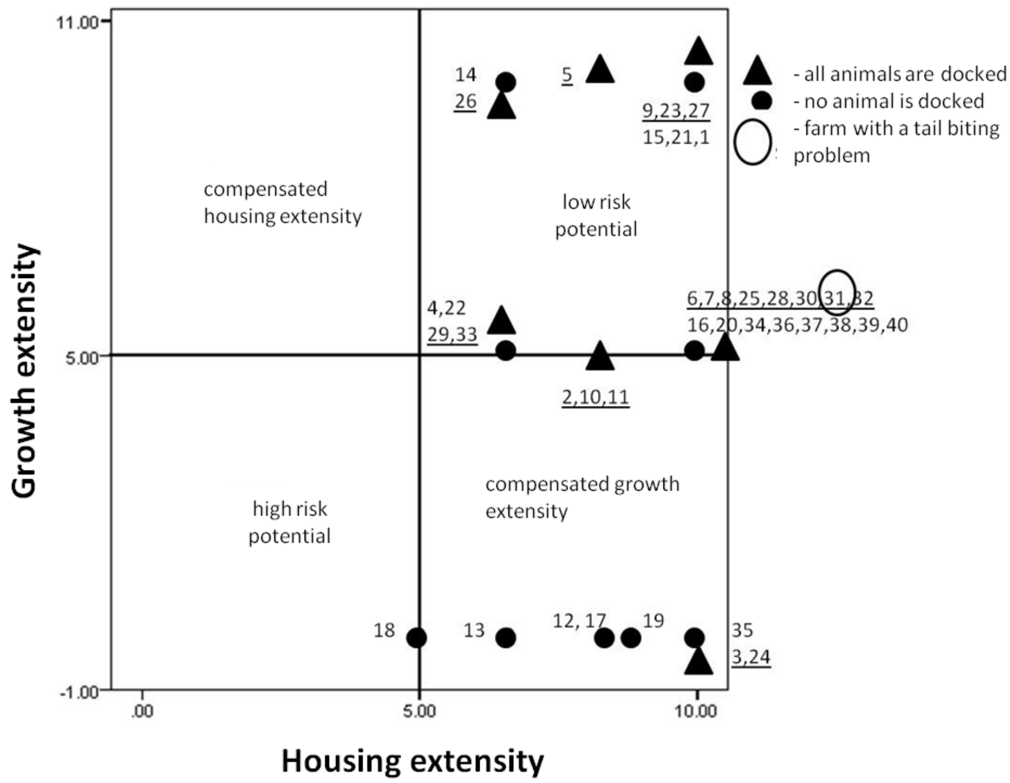


Figure 3.3: Portfolio for the relationship of housing extensity and growth extensity

Even here none of the farms–based on the determined parameters–fall into the lower left quadrant. This means that none of the farms have a “high risk potential” based on the growth of the mast animals and the housing conditions. Here, the upper right quadrant with “low risk potential” includes 80% of the farms.

The results of the principal-component analysis are presented in Figure 3.4. Component 1 is influenced by the activity and care intensity factors and explains 41.5 % of the total variance. The second component is mostly influenced by the calculated factor “growth intensity,” although the other three factors also have an influence on this component. It is 26.0% of the total variance. With 67.5% total variance, the test according to Homburg (1995) is charged because of the two components.

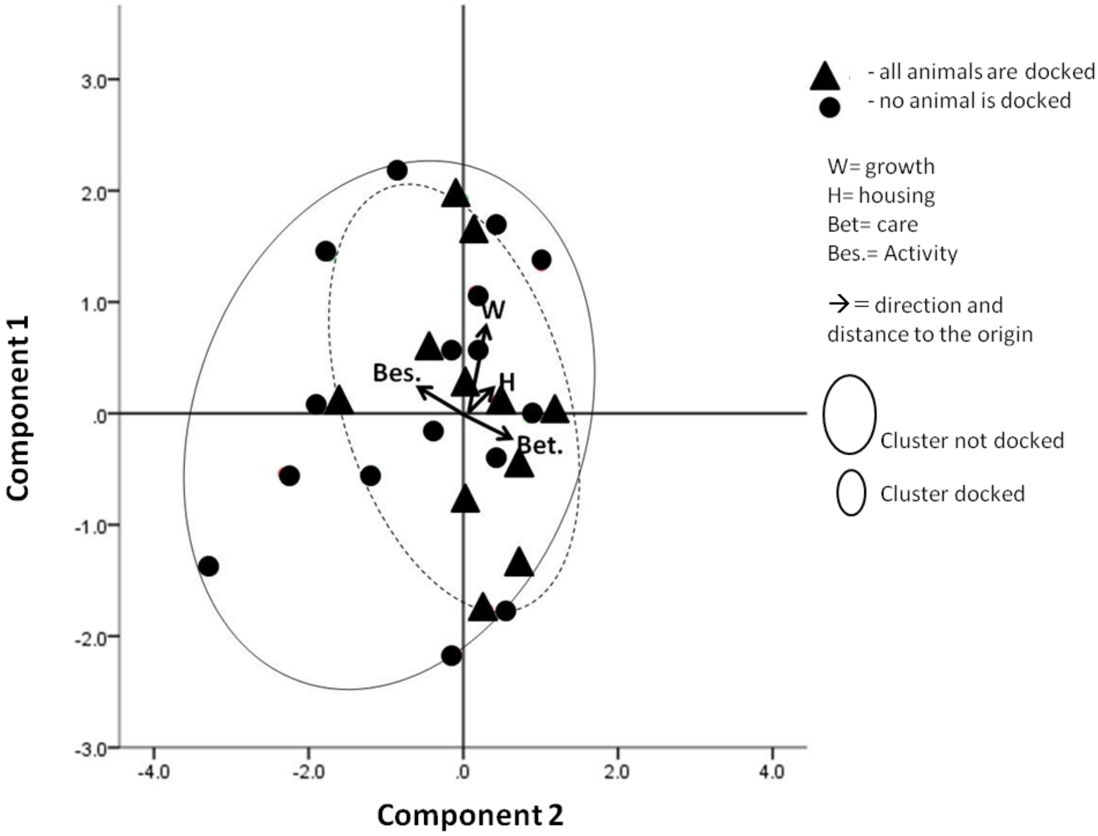


Figure 3.4: Results of the conducted main analysis based on the four factors of care (Bet.) and activity intensity (Bes.), as well as the housing (H) and growth extensity (W)

The more the factor is removed from the origin, the more important is the factor with respect to the variance of the farms for explaining the risk for tail biting. The growth factor has the biggest distance to the origin of the coordinate system and thus the biggest influence on the variance. The housing factor has the smallest distance to the origin of the coordinate system and thus has the lowest influence. Nevertheless, all four factors are very close to the origin. This confirms the hypothesis that tail biting is a multifactorial and complex problem, which cannot be explained with one influential variable. The cluster of the two different farm types shows that the farms that do not dock the tails have significantly bigger differences with respect to the factors of activity and growth.

3.5 Discussion

The results that are presented from the 40 audits and five expert rounds can be summarized as follows.

The experts were satisfied on the basis of the collected data in China that the risk for tail biting can be minimized by optimizing the operational management. Five typical causes could be identified in China and their associated measures characterized as follows:

- Avoid drafts to prevent avoidance behaviors in the choice of the relaxation area.
- Provide activity materials in order to satisfy any play and rummage behavior and to prevent replacement behavior.
- Stabilize the relationship between human and animal to avoid unrest in the stable during feeding and control.
- Identify aggressive animals in a timely fashion and discharge the aggressive animal timely.
- Increase the share of crude fiber to achieve an emotion of satiety during the intensive growth phases.

Farms in China feeding pigs without docked tails presented reasonable animal health management. In this group the loss rates from 90% of the farms were under 5%, whereas on farms where piglets' tails were cut only 30% were under the limit. This indicates additional health problems. On farms practicing tail cutting, 50% declared that at times they experience problems with tail biting. From the onsite audits, only one farm practicing tail cutting had problems with tail biting.

The results of the factor analysis show that there are farms that do not cut the tails, but which are very similar in many factors to the cutting farms. Other farms intensify the activity or reduce the growth rate to prevent these problems. According to one manager on a farm, cutting the tails were based on recommendations from European consultants. It seems like the managers of the Chinese farms accept European systems and recommended measures (tail cutting etc.) without being aware of the strengths of their own systems.

A study from Moinard et al. (2003) also confirms that on farms with a low loss rate, the occurrence of tail biting is rare. Unlike European farms, many farms in China feed vegetables or similar. Regarding measures to prevent or avoid cannibalism, the manager said that feed additives such as vitamins and minerals are used to supplement the pigs' feed. Extra vegetables give more structure to the food. Structural material plays an important role in prevention. This also confirms studies from Bround (1998), Colyer (1970), and Day et al. (2002). When crude fiber food–such as beet pulp, straw, hay, or apple tree brushwood–is given to pigs, it stimulates salivation and the swallowing activity. In this way the play activity can also be satisfied. Car tires, balls, and chains are unsuitable because of their lack of deformability (Pütz et al. 2011). On the Chinese farms air quality was consistently good during the audit period. According to EFSA (2007), this is also an important criterion. Avoiding drafts, keeping dust load as low as possible, and minimizing the harmful gas concentration is also, according to Hunter et al. (2001) and Tölle (2009), unquestioned.

Concerning the methods, how faults in air conditioning in stables can be measured, and how technical improvement measures can be developed economically, still require significant discussion. Moinard

(2003) specifies the size of the group as an influential factor. On Chinese farms the animals were in groups of between three and 20. Because of the more intensive personnel management (feeding, stable hygiene), the pigs' responses to events in their environment were less jumpy. Pigs reacted normally to the company of several people and did not demonstrate shyness. Therefore, animal observations took place often.

The typically intensive human animal relationship in the animal housing in China—because of several hours of stall work during the day—makes timely identification of aggressive animals possible, thereby effectively preventing the problem of tail biting. Because of the significantly higher labor wage in Europe, new methods and techniques must be developed to facilitate the timely identification of tail biters. The only way to stop tail biting is to separate the biting animal. On Chinese farms these animals were kept in isolation for several days. This animal losses its place in the order of ranks in the group, so it does not bite anymore when it is returned to the group. The Chinese animal housing systems are characterized by high intensity care, although the animals have no further activity materials.

The data and experiences that were collected to compare the Chinese and European systems have been interpreted by experts from agricultural science and veterinarians who concluded that the risk of tail biting in any housing or product system cannot be eliminated. There are always animals with behavior problems. This confirms also the study from EFSA (2007). A challenge is to discover, minimize, and stop company-specific stressors so that tail biting does not become a problem. There is agreement that when the well-being of the animals is very high, the danger for behavior disorders is the lowest (Knoop 2010). The question about painkiller use during cutting of the tails is important for veterinarians, as well as for farmers. According to the animal protection law, cutting tails from 4-day-old piglets or younger can be made without painkillers, but animal protection laws also provide that opportunities should be exploited to reduce pain and suffering. In the housing systems in Europe the semi-automatic feeding and air conditioning mean that the amount of time that people spend in the stable is very low; therefore, discovering animals with different behavior should be solved with supporting technical methods. For example, by measuring deviations from a normal noise level and noise profile, attention to biting pigs can be observed (Düpjan and Puppe 2011). In this regard a technology is installed that creates an alarm when noises differ from the normal level. This could be connected to an audio-video recording that could alert the farmer via his Smartphone. The farmer could then have a look at the video. He could immediately intervene in bigger rank fights, tail biting or similar without increasing the frequency of the stable visits.

3.6 Conclusions

The decision to dispense with tail cutting depends on three general conditions.

1. A clear signal from the market partner that unabridged and unharmed tails are regarded as indicators for the animal health and welfare. The criteria for the new animal labels are in the direction of, for example, “Aktion Tierwohl” from Westfleisch (Beuck 2011), “Better leven” from Albert Heijn (Stevering 2011), and the related animal welfare label from the initiative group “Tierwohl–Label” in Göttingen, which will bring the “Deutscher Tierschutzbund” to the market (Schröder 2011).
2. An offer from a consulting company for pig producers, fatteners in the supply chain, to the grocery trade, that marketing statements be passed onto the consumer. This also includes the waiver of piglet castration and the reduced use of antibiotics in the finishing period of fattening. The goal of such consultation is to achieve a high and constant health status of the stocks. Here, successful alliances have already been set up between farm holdings and vendor-appropriate support and advisory services (Schütz 2009, Ellebrecht 2012, Brinkmann et al. 2011).
3. Technical innovations should be taken into account to support animal observation and improve climate management in stables, as well as create feeding systems that encourage the search and chewing behavior of the animals.

The results from the comparison between the European and the Chinese farms have shown that housing of the animals—and not the basic setting of the management—will determine whether the behavior of some animals will become a problem.

4 Economic importance of alternative methods for castrating piglets without anesthesia, taking into account ethical and social requirements

Parts of this article have been published in German:

SOPHIA VERONIKA SCHULZE-GEISTHÖVEL[1], MICHAEL STEINMANN[2] (2012):

Wie sind die Alternativen zu bewerten?

In: Fleischwirtschaft 11/2012, Vol.92 S.14-20

[1] Institut für Tierwissenschaften, Abteilung Präventives Gesundheitsmanagement, Rheinische Friedrich-Wilhelms-Universität Bonn, Katzenburgweg 7-9, D-53115 Bonn

[2] Institut für Lebensmittel- und Ressourcenökonomik, Abteilung Produktions- und Umweltökonomik, Rheinische Friedrich-Wilhelms-Universität Bonn Meckenheimer Allee 174, D-53115 Bonn

*Corresponding author: Sophia V. Schulze-Geisthövel.
Email: s.schulze-geisthoevel@uni-bonn.de

4.1 Introduction

While castration of male piglets without anesthesia has in the past been linked with animal husbandry and was not questioned by society, it has in recent times been changing due to the public's perception of animal welfare.

Castration without anesthesia has been increasingly called into question, because castration in other species, such as house and pet animals, is performed only under anesthesia.

At the German Conference of Agriculture on 28 October 2011 in Suhl, ministers asked representatives of the agricultural departments of the country and the Federal Government to, no later than January 1, 2017, prohibit surgical castration of piglets without effective pain relief, at least until practical alternatives are found. Prior to this conference the German Farmers Association (DBV), the Meat Industry Association, (VDF) and the Central Association of German Retailers (HDE) agreed in a joint statement in September 2008 to the development of practical alternatives to castration under anesthesia. At the European level, a statement on alternatives to surgical castration of pigs was published in December 2010 as a result of a previously organized initiative by the European Commission workshops on the subject.[1] In the statement it was agreed that the surgical castration of pigs from January 1, 2012, if necessary, be carried out only after prolonged administration of painkillers and / or drugs, according to well established methods before being completly abandoned on Januar 1, 2018. In

[1] http://ec.europa.eu/food/animal/welfare/farm/docs/castration_pigs_declaration_de.pdf

Germany today about 95% of all pigs slaughtered are from programs that participation in the QS system in which castration is allowed only under pain-relief drugs.

The basic reason for castrating male piglets is that the meat of mature boars deviate from the European Union's market requirements of taste and odor. Therefore, both ethical and economic conflicts emerge because "the lack of acceptance of deviant in the smell and taste of boar meat stands of animal welfare commitments contrary to avoid pain, suffering and damage to the animals" (Link, 2008). For this reason alternatives must be found that bring the ethical requirements, social acceptance of modern animal husbandry methods, and the economics of pig production into line.

The aim of this paper was to evaluate—by surveys including economic evaluation—the economic impact of alternatives to castration without anesthesia in terms of their impact on the revenue and cost structure of piglet production and pig fattening. The surveys formed the base for the model calculations on the basis of performance cost accounting.

To this purpose the framework under which the castration of piglets in Germany takes place will be described first. Besides biological and animal protection law aspects, the growing ethical issues of modern animal husbandry procedures in general and especially the problem of piglet castration will be discussed. On this basis alternative procedures to piglet castration without anesthesia are explained, as well as the associated pros and cons. For purposes of an economic evaluation of possible alternative procedures, the results of a qualitative expert survey about alternative procedures to piglet castration without anesthesia are described and discussed in the third chapter of the presented study. On the basis of expert testimonies, imposed costs or benefits connected with the procedures serve as the economic analysis of the described alternative procedures in the fourth chapter. After a discussion of the results the work closes with conclusions for the praxis.

4.2 Framework conditions for piglet castration

4.2.1 Reasons for the castration and legal framework conditions

The main reason for the routine castration of pigs is, in contrast to other animal species, not for the prevention of aggressive behavior or unwanted pregnancies, but for preventing the development of the perceived different boar taint (Weiler et al. 2000, Font I Furnols et al. 2003). Boar taint develops under the influence of genetic and non-genetic factors (Bracher-Jakob 2000). The main components are the sex-specific pheromone androstenone and skatole in the digestive tract, as well as other substances (indole, phenols, short-chain fatty acids). Non-genetic factors that influence the typical boar taint include housing, feeding, transport, light management, and hygiene.

According to the EU, meat with a pronounced gender odor must be declared as unfit for human consumption and cannot be released for human consumption (see VO (EG) No. 854/2004, Art. 5, Section 2). On the basis of the EG animal byproducts hygiene regulation (2002), the product must be classified to category 2, meaning that further processing to dog food etcetera is not permitted.

Perception of the typical boar taint in meat has been extensively studied, but to date there is no procedure for detecting boar taint, for determining what is in line with human perception of boar taint, or for determining the content of the odor substances androstenone and skatole in meat (Götz et al. 2009). In German-speaking areas only a few studies have been conducted on consumer acceptance of boar meat, which is, for example, widespread in England. First findings suggest that German consumers would forego the purchase because of the perceived unpleasant smell (Matthews et al. 2000; Huber-Eicher 2008). However, it must be considered that in the evaluation of these and other results most of the interviewees had no personal experience with boar meat and they were not well informed about the castration procedure and possible alternatives.

During surgical castration without anesthesia, the scrotum of the piglet is cut, the testicle is brought out, and the vas deferens cut. Normally the wound is not closed, but is supplied with antibacterial spray or powder. In addition to the pain during the procedure, seen from strong vocalization, defensive movements, and higher cortisol and adrenalin values, this procedure produces postoperative pain, growth slumps, and behavior changes (Taylor and Weary 2000; Von Borell et al. 2000). Postoperative complications and/or lack of hygiene range from abscesses to death.

The current law management in Germany allows surgical castration without anesthesia in male piglets under 8 days (§ 5(3) 1a, TierSchG 2006). In older animals castration has to be performed by a veterinarian on anesthetized animals and with the use of painkillers. Generally, every anesthesia in Germany has to be accomplished by a licensed veterinarian (§ 5 (1), TierSchG 2006). According to the "EG-Ökoverordung," for organic farming the operative castration is permitted by trained professionals and the suffering of animals is to be relieved through the appropriate use of painkillers and /or anesthetics. During the transition period until December 31, 2011, a castration without anesthetic and/or analgesia was permitted (EG- ÖKOVERORDNUNG 2008 No. 889/2008, Chapter 2).

4.2.2 Ethical and social requirements

In addition to aspects of product quality in the field of animal husbandry, there is increasing public interest in the quality processes, including environmental, social, and ethical issues. Due to the Brundtland report from 1987 and the spread of the term "sustainability," these are being discussed at all levels of society. For animal housing, increased social demands have followed. Due to various food scandals, this has led at a company level to a new sense of responsibility.[2]

For the meat economy this has resulted in an increased requirement to respond to social demands and find workable solutions for the whole value chain. For this reason more and more companies have brought animal-well labels onto the market; for example, "Aktion Tierwohl" from Westfleisch (Beuck 2011), "Better leven" from Albert Heijn (Steverink 2011), and the related development of the animal-well labels from the Göttingen initiative group, which the German animal protection group will bring to the market (Schröder 2011).

[2] The takeover of responsibility for the company's activities in ecological, economic and social regard shall be taken today under the term Corporate Social Responsibility (CSR) (Simons et al. 2011).

The ethical values regarding the kinds of housing for farm animals is of fundamental interest. The starting point for an ethical assessment is a modified pathocentric approach (pathos=suffer) were moral significance is attributed to creatures with perceptual ability and capacity to suffer. Increasingly animals are attributed an inherent value (Busch 2006). If animals have natural feelings and have a moral self-worth independent of human interest, they should be protected (Marggraf and Streb 1997). On the basis of this argument, human handling of animals is assessed.

For this purpose both the acceptance of responsibility for the animals and the awareness that there are restrictions, for instance in the form of interventions to the animal, are considered. In animal husbandry ethics form the starting point for reflecting our handling of production animals and has legal binding regulations, which are stated in the animal welfare law. In this way basic ethical views can be translated into social needs or requirements.[3]

To this effect the animal welfare law came into effect in 1972. Since then it has been revised several times to cover the current requirements of society. In this context the highest guideline, expressed by § 1 of Animal Welfare Law, states that the responsibility of humans for animals as fellow creatures is to save their lives, protect their welfare, and to prohibit causing animals pain, suffering, and damage without good reason (see § 1, TierSchG).

Analogous to the definition by the Farm Animal Welfare Committee[4] about the five general freedoms for animals, there are regulations in the second chapter of the German Animal Welfare Law about satisfying the needs of different animals in animal husbandry. Some of these needs include (see § 2, TierSchG):

- adequate nutrition—appropriate to the species—care and accommodation that considers the animal's behavior,
- cease restricting an animal's natural movement, particularly if it causes pain or suffering or damages the animal.

The increasing importance of animal welfare was also expressed in 2002 in the change in article 20 a of the basic law. Following the change animals get explicit protection in the framework of the constitutional order through the legislation (Art. 20 a, GG).

With respect to castrating piglets without anesthesia, from the aforementioned discussion, an immediate conflict between ethical and animal protection law arises, because the boundary issues between ethically permissible and legally permissible withiare not clear. Section § 1 of the animal protection law deals with the infliction of pain, suffering or damage, and explicitly restricts these "without good reason." Within society this is basically used for justifying ethical criteria (Busch and Kunzmann 2004). The concepts of pain, suffering, and damage have to be differentiated in this context. Damage can be understood as injuries that could lead to short-, medium- or long-term impairment of the animal. Pain results as a consequence of damage or injuries that arise directly from non-engagement of an animal or as a consequence of violations. Prolonged pain due to damage or injury with physical and/or physical im-

[3] In this context Busch and Kunzmann (2006) refer to the impossibility to derive ethical admissibility from legal admissibility.
[4] http://www.defra.gov.uk/fawc/about/five-freedoms/.

pairments can be grasped in general under the concept of suffering (see Busch und Kunzmann 2004Thus, suffering is in principle prevention from an ethical point of view.

Possible impairment to the animal and his behavior within the livestock, provided that no generally questioning the concept of livestock, must be prevented. Humans determine, for example, the feeding and the reproduction of the animals on their farms. Therefore, the farmer has a targeted influence on the biological and species-specific productivity of his animals. Such influential opportunities are limited by the state of knowledge of the biological contexts of the animals, as well as technological opportunities. This led in the past to the fact that in the context of the mast pig housing, male animals are castrated because they develop a sex-specific smell. Previously pain relief requirements were largely disregarded; however, they are being increasingly demanded as part of the social and ethical debate. Should piglet castration without anesthesia become possible due to technical advances and derived alternatives, then in the animal prevention law the statement “without good reason” loses its entitlement. Because of the term “good reason,” castration without anesthesia has been conducted until now, and will exist only as long as there are no alternatives to the status quo. Alternative procedures to piglet castration without anesthesia need to be introduced in an effort to come closer to the use of the “best available technology” (Busch and Kunzmann 2004). So, against the background that there are alternatives to piglet castration without anesthesia, ethical and social requirements must be met; also, modern animal housing methods must be accepted, safeguarded, or promoted for the consumer.

4.3 Alternatives to piglet castration without anesthesia

Two alternatives to castration without anesthesia are castration with anesthesia and/or the use of painkillers. In addition, vaccination against boar smell by two vaccinations is possible. For this option the boar must have a waiver of castration and be segregated in the slaughterhouse. Alternatively, the slaughter of boars before they become sexually mature could be practiced. Also, sperm sexing to reduce the number of male animals is a good possibility, as well as influencing the boar smell feature through breeding.

4.3.1 Surgical castration under anesthetic

For castration under anesthesia, the anesthetic can occur locally (topically or as an injection) or as a full narcosis in the form of an injection or inhalation. For castration with the use of painkillers, as required in the QS system, the drugs are injected once intramuscularly before surgery, which mitigates postoperative pain. However, pain during castration will not be diminished. From an animal welfare point of view, a combination of both methods—anesthesia and analgesia—is useful. According to the practical experience of the Swine Health Service of the North Rhine-Westphalia agricultural chamber, for castration with painkillers a tripartite procedure is recommended. For this the male piglets are treated with painkiller and separated from the female animals. Routine work can be performed with the female animals for 15 to 20 minutes while the painkillers in the males become effective. Thereafter, the male animals are castrated (Adam, 2009In this way, piglet castration with anesthesia can be organized despite the additional wait time and is economically advantageous.

4.3.2 Vaccination against boar smell

Vaccination against boar smell takes a different approach. Here, the pig's own immune system is stimulated by the vaccination to build antibodies against the gonadotropin-releasing hormone, so that the function of the testicle is temporarily set. The vaccination is performed twice and can take place in the mast operation. The effectiveness of the vaccine occurs after the second vaccination, what takes place 4 to 6 weeks before slaughter. Already-formed smell substances are degraded and new formation is prevented. The first vaccination takes place 4 weeks before the second vaccination (von Borell, 2010). The successful control occurs via the weight of the testicles. This process shows a high degree of practicability and considers animal welfare.

4.3.3 Boar fattening

One possibility for completely renouncing any kind of castration is boar fattening. It is still unclear how this should be implemented and whether transitional solutions are needed. An important obstacle right now is that clear recognition and separation of smelling boars at the slaughter assembly line occurs by an "electronic nose" or another automated system, which currently is not guaranteed. Also, in terms of composition and proceeding, carcasses of young boars are different, and for this reason adjustments in battlefield operation and market, as well as the classification and accounting masks, are necessary. In the mast boar the question arises of whether housing in separated groups or in mixed-sex groups is better. However, suitable activity possibilities are essential to intercept increased aggression potential and to prevent behavior problems. With increasing age the risk of boar smell increases, so the slaughter of these animals is often earlier. First experiences indicate that expression of the smell can be influenced specifically by the feed (Hansen et al. 2006; Zamaratskaia and Squires 2009; Fredriksen et al. 2007; Kagfreiland 2007).

4.3.4 Sperm sexing

From the keyword sperm sexing it is understood that sperm are preselected before artificial insemination. Hereby only female pigs could be produced. The technology is based on the different weights of the sex chromosomes. However, it is not 100% successful and, therefore, an additional solution for the boar problem has to be found. Furthermore, for intrauterine insemination in the pig a high sperm volume with a high number of sperm are necessary. For this reason the process is hardly used in commercial pig production (Alm et al. 2006).

4.3.5 Breeding

An approach at the genetic level is to search for genes that cause the boar smell. Physiological candidate genes have been analyzed with high throughput typing with SNP chips (Single nucleotide polymorphism), with the goal of finding interesting regions and candidate genes (Grindflek 2008; Archibald 2008; Harlizius et al. 2009). For this method sufficient material is required from animals with the known phenomenon. A clear disadvantage of this method is that the relationship between markers and features is race specific and has to be determined in each population. In addition, studies have shown that the chromosome regions of interest have genes with a positive influence on fertility, which of course should not be eliminated (Grindflek et al. 2010). Model calculations show that genetic selection against high androstenone values have a large probability of being successful. However, even under optimistic assumptions, the antagonistic trait relationship between boar smell and fertility is expected to occur for a period of at least 8 to 12 years spanning 4 to 6 generations (Tholen and Frieden 2010; Frieden et al. 2011). Also, the development of appropriate proof procedures to test living boars for boar smell is essential.

4.4 Survey regarding alternatives to piglet castration without anesthetics

Due to the high specialization of pork production, as well as an increasingly close interdependence of the different steps along the whole value chain, the problem of "piglet castration" cannot be solved only on the agricultural level. For a general assessment and evaluation of alternative procedures to piglet castration without anesthetic, an expert survey along the value chain appears useful. As part of this project the survey was performed along the pork value chain. Twelve representatives from all key stages of the value chain were interviewed.

The sections examined along the pork value chain are schematically shown in Figure 4.1. Experts were interviewed regarding piglet castration and possible alternatives. The interviewees include representatives from the feedstuff industry, agriculture (piglet producers and fatteners), and the slaughter industry (including processing).

At the level of agriculture the adviser to the Chamber of Agriculture of North Rhine-Westphalia, as well as supervising veterinarians, were also interviewed.

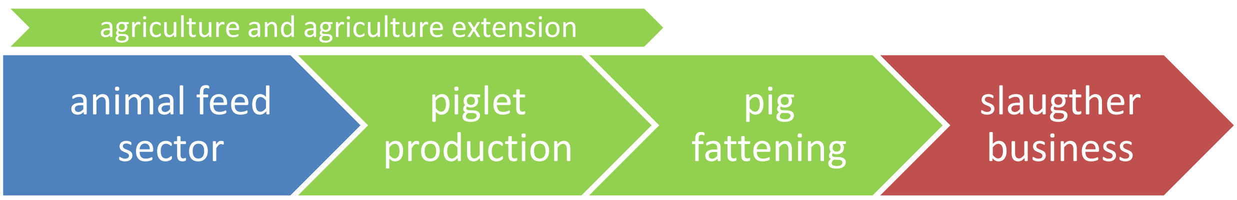


Figure 4.1: Stages of the pork value chain that were analyzed

For a structured discussion a thematic guide proved helpful. The first section of the interview guide consisted of general questions. The topics included economics, animal welfare aspects, and an assessment by the experts about consumer knowledge of piglet castration using different methods and acceptance by consumers of these methods. Furthermore, the assessment was levied on the future of the various methods. The general part of the survey was used to obtain from the experts a basic self-assessment in terms of knowledge of alternative methods.

According to the assessment, the most widely accepted long-term method among consumers is boar fattening, with reviews of *good* and *very well* being proportionately favored. This is also consistent with the experts' assessments about which alternative method will apply in the long term. Here, all 12 experts agreed that boar fattening is the method of choice for the future.

The focus of the second part of the interview guide was on the following procedures:

- surgical castration under anesthesia (analgesia and / or anesthesia),
- vaccination against boar taint, and
- young boar fattening.

Questions remain about the procedures that relate to, among others, the implementation and cost, marketing of the pigs, changes in the meat associated with the procedure, and the respective advantages and disadvantages of the procedures. Any additional cost of the various alternatives were compared to the castration of piglets without anesthesia and was given partly in the form of additional time spent due to additional work that may be required, but also directly in the form a monetary amount. Different standards have been expressed for the economic comparison of alternative methods uniformly as costs or benefits.

4.4.1 Surgical castration under anesthetic

Surgical castration under analgesia

For the procedure of surgical castration under analgesia (i.e., administration of the analgesic) piglet producers and fattening producers, as well as several agricultural consultants, were interviewed. On the question concerning which medical preparation is applied for surgical castration with analgesia, all respondents said that Metacam is used. Metacam® (5mg/ml) injectable solution is administered to cattle and pigs for the relief of postoperative pain associated with minor soft tissue surgery, including castration in pigs. There is a product that has been approved for the treatment of pain in piglet castration (ZDS, 2010), and is available to veterinarians and pig farmers. In the best case, on the third day of the male piglet's life 0.2 ml of the agent is injected intramuscularly in the neck 15 minutes prior to castration. The experts appreciate the added effort of administering the agent amounts to 2 to 3 seconds more per male piglet than surgical castration without anesthesia. However, neither the agronomic consultants nor the piglet producers knew of higher animal losses due to the treatment. Farmers confirmed that following piglet castration, no further expenditure of time for special aftercare is needed. The cost of the procedure consisted mainly of the cost of the drug and the needles and syringes required for the treatment.

In assessing the analgesic effects in piglets, a basic distinction should be made between the phase of castration and the time after castration. The effects of the analgesics in piglets during castration received a mixed response from the respondents. Feedback ranged from no pain relief to low pain relief to more vital piglets after castration. The experts were highly satisfied with the postoperative pain relief in piglets compared to piglet castration without anesthesia. In their opinion, postoperative pain appears to be significantly less than castration without anesthesia. Overall, the procedure with analgesia was judged to be an appropriate transitional solution, which, according to the experts, takes account of the animal protection law claims.

Surgical castration under anesthesia

Only a small number of non-conventional farms in Germany use the method of surgical castration under anesthesia. Therefore, only the agricultural consultants who had been informed about this process or had gained experience during their consultations were interviewed.

Two different anesthetic techniques are available; they distinguish between isoflurane and CO_2 narcosis. Both anesthetics are administered via inhalation mask before the castration procedure. According to German law (§5(1) TierSchG), the anesthesia must be performed by a veterinarian. From the perspective of the consultants interviewed, both isoflurane and CO_2 narcosis mean significantly higher material and time costs for the farmer. The additional time effort amounts to about half an hour. This time is needed for the positioning and preparation of the mobile anesthetic machine, the procedure of the narcosis self (about 60 seconds), and control of the piglet during the wake-up phase after the castration.

The incurred cost of isoflurane anesthesia, according to experts, with the cost for the mobile anesthetic machine, amounts to 6,000–7,000 €, while the tubes for the narcosis amount to 600–700 €. Other studies act on the assumption of ca. 10,000 € for the anesthetic machine. Furthermore, both procedures incur costs for veterinarians. According to the experts' assessments, the cost for the inhalation narcosis is ca. 2.3 € per piglet.

Both anesthesia procedures are associated with risks for the piglets in the form of violation, possible hypothermia, or even death. More known risks include reduced respiration, a clear blood pressure drop, and a slowed heartbeat. Another point of criticism is the hygiene, because the anesthetic machine is perhaps provided by the veterinarian and is driven from farm to farm. Furthermore, narcotics are problematic since they are classified with regard to employment protection. In addition, isoflurane is supposed to be a gas which is harmful to the ozone.

The interviewees clearly differed in their statements regarding pain relief in piglets during castration. Their opinions ranged from good to bad pain relief to no pain relief. All experts agreed that postoperative pain in the animals compared to the pain after a castration without anesthesia are basically the same, which is why the procedure should be complemented by providing painkillers. This would ensure ideal pain relief during and after the castration. In the meantime, there was consensus that castration under CO_2 gas is not recommended (Waldmann et al. 2010; Kohler et al. 1988; Svendsen 2006; Mühlbauer et al. 2009; Kluivers-Poodt et al. 2007).

The conclusion is that the cost for surgical castration under anesthesia is very high, and can even result in animal loss. Moreover, only veterinarians are allowed to practice it, which causes an additional organizational hurdle and an economic load.

4.4.2 Vaccination against boar odor

Several agricultural advisers were interviewed about vaccinating against boar odor. The procedure of vaccinating against boar odor is projected by both farmers and responsible advisers to be comparatively uncomplicated. This is based on experiences from a vaccination attempt on boars. Both the farmer on whose farm the attempt was performed and the corresponding adviser both specified that the procedure is uncomplicated.

With a view to fattening performance, the pigs can be slaughtered at a younger age. Because of higher weight gains the carcass weight, according to the experts, remains approximately unchanged. However, the male and female pigs have to be kept separate because, among other things, they receive different feed. The daily weight gains up to the second vaccination of the animals are the same as the boars, but after the second vaccination they are higher than the boars. This gain against the background of rising cost for feeding is important for the efficiency of pig fattening. With regard to a possible improvement in the feed conversion rate of the vaccinated boars compared to the unvaccinated boars, the experts had divided opinions.

According to the experts an additional time requirement arises for implementing the vaccination. The fatter, who performed the vaccination against boar odor for experimental purposes, specified that vaccination required on average ca. 18 seconds per animal. The cost for both vaccinations are around 4–5 € per animal. The vaccination control can be performed visually by the farmer, because after successful vaccination the scrotum descends after a short period of time and the skin wrinkles. According to the producer of the preparation, there is no vaccination failure if correctly applied.

The chances of commercializing the meat of pigs vaccinated against boar odor, according to all interviewees, is difficult because the market does not take the meat so far. Possible reasons are that consumers may have reservations against this procedure and associate it with “hormone treated” meat (Huber-Eicher 2008) or even with a more excessive use of drugs in animal husbandry. However, to date no objective dangers to human beings have been associated with consuming meat from vaccinated animals. Therefore, it can be concluded that both information and communication deficits exist with regard to the procedure of vaccinating against boar odor, which leads to a rejection of this procedure.

According to statements from the agricultural advisers, the advantages of vaccinating against boar odor include the following: a higher biological power against castrated boars, a higher level of weight gain, unchanged meat texture, the absence of noticeable olfactory aspects, and avoidance of the castration procedure.

Although the vaccination is unproblematic, disadvantages arise on the one hand from a higher amount of work due to the second vaccination, the occupational safety during the vaccination (because the medium can have an effect on the user through accidental administration), and the problem of catching the optimal time, while on the other hand vaccinated boars need to be kept separated due to their requirements for special food for their fattening. Another disadvantage, which becomes the exclusion criterion for this procedure, is that the vaccinated pigs cannot be sold to slaughterhouses. Slaughterhouses justify the exclusion of these animals by consumers' lack of acceptance.

4.4.3 Fattening of young boars

Since boar fattening–at least long term–may become the only accepted alternative to piglet castration without anesthesia, an extensive opinion throughout the value chain is necessary. A fatter, several agricultural advisers, several slaughterhouses, and several feed businesses were interviewed regarding the procedure of fattening young boars.

Concerning fattening performance, the opinions of the interviewed fatters differed from the agricultural advisers. The former specified that the boars are ready for slaughter 14 days earlier than sows and castrated boars, whereas the agricultural advisers did not note any difference in the feeding performance. Regarding the slaughter weight, all experts agreed that it did not differ significantly from the marketable slaughter weight. The problem here is that there is no recognized classification for boars that makes an earlier slaughter attractive.

With regard to the rearing method, the fatters, advisers, and feed businesses had the same opinion that because of the different feeding demands of sows and boars, the animals have to be separated. Furthermore, with a view to exhausting the growth potential, the origin of the piglets and also the management plays an important role.

According to the interviewees, the group size in boar rearing can be created according to the operation of the individual farm. The fatters believe that there is more work in the changeover period to boar fattening. Due to the requirements of increased animal monitoring and the need to keep the sexes separate during the feed changeover, adoptions or restructurings on the management level are necessary. General requirements in the area of the boar fattening result, in particular, in more intense animal monitoring in the second meta section, because the aggressive behavior against ill or weak animals within the stable bay is much stronger by boars in the beginning of sexual maturity than by sows. This requires a higher amount of working time. However, the experts in breeding agreed that placing and the beginning of fattening are not associated with known noticeable negative sexual behavior or aggressive behavior that requires additional effort.

In evaluating the economic efficiency of boar fattening, the interviewed farmers and agricultural advisers agreed that several factors need to be considered. While the cost for food increases owing to the recommended higher amount of lysine, the food conversion ratio of the boars improves. For this reason, the biological achievement potential is more likely to be exhausted; for instance, through higher daily weight gains and a better lean meat content. The difference in cost between conventional food and special food for young boar fattening is, according to the fatters, approximately 1.5 €/dt, although the difference depends on the general price level for crops and protein food. According to the fatters, the monetary advantage in revenues for boars compared to castrated boars is currently approximately 3 € per pig.

From an agricultural viewpoint, the advantages of young boar fattening are, therefore, the better food conversion ratio, higher daily weight gains, an improvement in animal welfare because of the vaccination waiver, the working time savings because of the vaccination waiver, a possible advantage in hygiene with a resulting increase in animal health, as well as economic advantages because of higher biological power and a higher lean meat content. As a disadvantage, the farmers and agricultural advisers debated the danger of consumer irritation, for example, because of the odor problem.

At the level of the agricultural producers, boar fattening could have structural implications, because keeping the sexes separated requires specialization of fatting farms into boar and sow fattening.

The feed businesses that were interviewed have, with the exception of one company, still no special food for young boar fattening in their product range. Indeed, the development of special food for boar fattening is ongoing. According to the food businesses interviewed, the challenge exists in developing a food specifically for boars since, in reference to the food conversion ratio, the protein supply and the meat growth must be optimally adjusted for boars. The difference in cost between conventional food and the special food for young boar fattening is estimated at 1 to 2 €/dt of food. The attractiveness of using special boar food increases according to a statement of one food business about constantly rising food prices. The food conversion ratio could be increased by approximately 0.2–0.3 towards the normal level, and this aspect is of special economic interest for the pig fatters. Furthermore, the problematic development of boar odor could be influenced by the food. One of the food businesses that were interviewed is carrying out tests that deal with the interaction of food and the development of odor.

Regarding the interviewed slaughterhouses, the bigger companies evaluated boar fattening as positive. Both of the interviewed slaughterhouses comply with specifications of the QS system and slaughter only those pigs that are castrated under pain relief or boars. In contrast, the smaller slaughterhouses rejected boar fattening because of organizational problems in detecting odor, which tends to decline. It is clear that procedural changes for larger companies appear less problematic than for smaller abattoirs, probably due to advantages in the implementation of new methods. In this context the structure effect emanating from significant changes in the process flow of slaughterhouses must not be underestimated. In this respect it is assumed that large abattoirs have great advantages over smaller firms and this further strengthens the already existing competitive advantages. This could result in a further concentration of the slaughter industry.

The additional work that is associated with the slaughter of boars at the slaughterhouse—because of gender segregation and odor detection—vary according to the slaughterhouse. Gender detection and selection on the slaughter line takes place manually at the slaughterhouse by staff, but can also be done by image recognition and a chip in the transponder. The additional cost for slaughter companies is 0.50 € per animal for the former method and 1 to 2 € per pig for the latter method. In the interviewed slaughter companies there is currently still no change in the transport logistics for young boar slaughtering.

The marketing of boars is due to relatively strong current demand. The process of young boar fattening is desirable to consumers because of their view of high animal welfare. This would, therefore, be welcomed by the food retail sector. In order to follow this trend the surveyed slaughter companies will increase the number of boars slaughtered in the future. For one of the interviewed slaughter companies, boar meat is supplied exclusively to customers who order it; another company currently exclusively exports boar meat to Holland. There are various food retailers that now offer meat from sows and boars. In this regard it is clear that attitude towards the process of fattening pigs and, optionally, alternative methods to piglet castration without anesthesia are influenced by the demand.

The value of boar meat production is largely determined by the payment of value-determining sections. Due to the narrowly defined areas in the size of the cuts, there is significant divergence in the slaughter weight of boars that still acts negatively on the revenue. The opinion on the slaughter weight varies between the different companies. One of the surveyed companies generally assume that the slaughter weights will remain at the current level, while another company expects the slaughter weight of young boars to be lower than the fattening and slaughtering weights in pigs today.

In terms of the settlement, the slaughter companies offer a model for boars, which in addition to auto-FOM-classification takes into account some other system benchmarks. The billing model initially includes a basic deduction from the base price, which is intended to represent the cost of the additional costs of controls and sorting measures in the slaughterhouse. The span for the deduction from VEZG-cost (Vereinigung der Erzeugergemeinschaften für Vieh und Fleisch e.V.) is given by the surveyed companies with 2 to 3 cents per kilogram slaughter weight. With the exception of the cost of inspection and sorting the proportion of smell deviants, there is no connection with the payment in a pig batch among the surveyed slaughter companies. The surveyed slaughter companies have not yet agreed on whether a stand-alone billing mask is necessary for boars.

4.5 Discussion and conclusions

In view of the prohibited castration of piglets without anesthesia, alternative methods are under discussion. With this background, this paper aimed to evaluate economically various alternatives to the castration of piglets without anesthesia.

Cost comparisons of the elective alternative methods suggest boar fattening as the most advantageous. This procedure basically fulfills all ethical and social requirements. However, the industry is facing new challenges. In boar fattening there are a number of open questions that must be solved. This includes the question of how a complete system change would affect a brand of potential boar meat. Although boar meat currently markets relatively well, it remains open whether the market is able to absorb the total volume of boar meat and whether the same value will be achieved as in today's market of the meat of gilts and castrated boars. The extent to which the processing and marketing of boar meat in the future is a problem will largely be determined by the proportion of animals in which the meat has variations in odor and taste. It can be stated that due to the requirements for the type and quality of products, possible adjustments in pork production due to current economic and legal conditions have narrow limits. Although current policy generally allows various action options as alternatives to castration without anesthesia, it is evident that there is no free choice of alternative procedures for the agricultural sector. For example, changing the Animal Protection Act in relation of the conditions for use of isoflurane in piglet castration would offer alternatives.

While legal foundations constitute the general framework for possible alternatives, it is already apparent that trade, for example, animal welfare labels, and other requirements of possible alternative methods for castration without anesthesia must be determined. Apart from the cost of possible alternative methods, another question addresses the issue of marketing importance, because increases in the value of livestock enterprises extend the possibility of an adapted form of housing, as well as those interventional procedures already used on animals.

5 Analysis of transmission of MRSA and ESBL-E among pigs and farm personnel

This article has been published in English:

RICARDA MARIA SCHMITHAUSEN[§1,2], SOPHIA VERONIKA SCHULZE-GEISTHOEVEL[§2], FRANZISKA STEMMER[2], MOHAMED EL-JADE[1], MARION REIF[1], SYLVIA HACK[4], ALINA MEILAENDER[1], GABRIELE MONTABAUER[1], ROLF FIMMERS[3], MARIJO PARCINA[1], ACHIM HOERAUF[1], MARTIN EXNER[4], BRIGITTE PETERSEN[2], GABRIELE BIERBAUM*[1], ISABELLE BEKEREDJIAN-DING*[1,5]

Analysis of transmission of MRSA and ESBL-E among pigs and farm personnel

In: PLoS ONE (accepted)

[1] Institute of Medical Microbiology, Immunology and Parasitology, University Hospital Bonn, Sigmund-Freud-Str. 25, D-53105 Bonn, Germany

[2] Institute of Animal Science, Preventive Health Management Group, University of Bonn, Katzenburgweg 7-9, D-53115 Bonn, Germany

[3] Institute of Medical Biometry, Epidemiology and Computer Science, Sigmund-Freud-Str. 25, D-53105 Bonn, Germany

[4] Institute of Hygiene and Public Health, University Hospital Bonn, Sigmund-Freud-Str. 25, D-53105 Bonn, Germany

[5] Division of EU cooperation/ Microbiology, Paul-Ehrlich-Institute, Paul-Ehrlich-Str. 51-59, D-63225 Langen, Germany

[§] and * Authors contributed equally to the study

5.1 Abstract

Livestock-associated multidrug-resistant bacteria have heightened our awareness for the consequences of antibiotic consumption and spread of resistant bacterial strains in the veterinary field. In this study we studied the prevalence of methicillin-resistant *Staphylococcus aureus* (MRSA) and enterobacteriaceae expressing extended-spectrum betalactamases (ESBL-E) and compared their prevalence at different stages of pig production to that in air samples from the stables and humans living and working on the farms. Nasal colonization with MRSA (113/547 pigs (20.7%) was less frequent than rectal colonization with ESBL-E (163/540 pigs (30.2%). On the farm level MRSA correlated with ESBL-E recovery. Notably, MRSA was detected in stable air samples of 34 out of 35 pig farms, highlighting air as an important MRSA transmission reservoir, but ESBL-E detection was limited to 6 farms. Most MRSA isolates, including those from humans, displayed tetracycline resistance and *spa* types t011 and t034 characteristic for LA-MRSA, demonstrating transmission from pigs to humans. ESBL-E were mostly *Escherichia coli* with CTX-M-type ESBL. Molecular typing revealed transmission of ESBL-E within the pig compartment; however, related strains were also found on unrelated farms. ESBL-E positive air samples were detected on 6 out of 35 farms and no pig-to-human transmission was found. Our data suggest that acquisition of MRSA and ESBL-E might occur among pigs in the abattoirs, MRSA and ESBL-E were not detected on the carcasses. Altogether, our data define stable air (MRSA), pig compartments (ESBL-E) and abattoir waiting areas (MRSA and ESBL-E) as major hot spots for transmission of MRSA and/or ESBL-E along the pig production chain.

Key words:

MRSA; ESBL-E; pigs; livestock; antibiotic resistance; multi-drug resistance; air; human; transmission; DiversiLab

5.2 Introduction

For several decades there has been an intense debate whether the use of antibiotics intended to reduce infections in livestock and to promote growth (not allowed in E.U. (Hammerum et al. 2007) leads to the development of antibiotic resistances (Gilchrist et al. 2007; Hawkey and Jones 2009; Mathew et al. 2007; Threlfall et al. 2000). We have also become aware that resistances emerging in livestock are not confined to animals: Firstly, with glycopeptide resistance as a prominent example, we have observed that resistance genes can make their way into bacterial species that are more virulent for humans than those where the resistance was first observed (Hiramatsu et al. 2002; Nübel et al. 2010; Strommenger et al. 2014). Secondly, with the increasing prevalence of LA-MRSA we are experiencing the spread of livestock associated resistant pathogens to humans (Cuny et al. 2013; Cuny et al. 2009; Graveland et al. 2011a; Graveland et al. 2011b; VAN DEN Broek et al. 2009; van Loo et al. 2007).

Despite all achievements in hygiene and technology one of the major challenges in health care in developed countries is the prevention and treatment of nosocomial infections. The major threat is the silent spread of colonizing multidrug resistant pathogens among patients with overt risk for acquisition of resistant bacteria and – even worse – into those with no history of hospitalization or travel (Bootsma et al. 2011; Jakobsen et al. 2010). These colonizers represent the major source for endogenous infections that occur after surgery, chemotherapy or other medical treatments associated with transient or prolonged immune suppression. The major dangers associated with these infections are the unexpected lack of effectiveness of antibiotic therapy in a severely ill patient and the uncontrolled spread of these organisms in the hospital environment.

In views of these consequences the landscape within the research field dealing with bacterial resistance has changed. It has become evident that apart from describing the genetically based resistance mechanisms it is additionally necessary to study the origins and habitats of resistant bacteria. This is especially important because multidrug resistance not only implies the acquisition of genes mediating resistance against different classes of antibiotics but is also associated with resistance to bacteriotoxic environmental conditions such as exposition towards heavy metals or disinfectants (Leelaporn et al. 1994; Littlejohn et al. 1992; Seiler and Berendonk 2012). This trend has also fostered research in the agricultural field, which addresses the consequences of antibiotic consumption in the veterinary field, including the assessment of the potential role of livestock as a reservoir for transmission of multidrug resistant bacteria to the human host (Cuny et al. 2009; Leverstein-van Hall et al. 2011).

Methicillin-resistant *Staphylococcus aureus* (MRSA) is one of the most widely studied resistant bacterial species in this context. Epidemiologically discernable livestock-associated (LA-) MRSA strains have evolved next to the community acquired (CA-) and hospital acquired (HA-) MRSA lineages. The LA-MRSA strains have particularly adapted to pigs as hosts (de Neeling et al. 2007) and have been detected at all different levels of the pig production chain (Beneke et al. 2011; Lassok and Tenhagen 2013; van Duijkeren et al. 2008). Notably, LA-MRSA strains have been isolated from persons who are in close contact with pigs and they are more frequently detected in hospitals within rural areas (Monaco et al. 2013; van Cleef et al. 2010; Wulf et al. 2012).

More recent work has described the emergence of enterobacteriaceae resistant to betalactam antibiotics expressing extended beta lactamases (ESBL-E) in pig (Geser et al. 2011). ESBL-E frequencies among patients have increased worldwide. This propagates the broad use of betalactamase inhibitors and further selection of highly resistant strains (Nedbalcova et al. 2014; Pitout et al. 1997). When combined with quinolone resistance, ESBL expression poses a serious clinical problem due to limited options for oral antibiotic therapy, which make intravenous administration and hospitalization of the patient necessary. Evidently, the limited number of orally absorbed antibiotics available will also have important impact on antibiotic usage in pig farming. Furthermore, new hygiene measures need to prevent that colonized pigs or their meat turn into a new reservoir for transmission of ESBL-E to humans (Geser et al. 2012a; Geser et al. 2012b; Horton et al. 2011; Leverstein-van Hall et al. 2011; Marshall and Levy 2011).

In the present study we assessed the prevalence of simultaneous ESBL-E and MRSA colonization throughout the pig production chain (from piglets to carcasses) and related these findings with MRSA and ESBL-E recovery from air samples and humans living and working on farms.

5.3 Material and Methods

5.3.1 Study design and sampling approach

The cross sectional followed nearly all steps of the pig production chain. The study was divided in two parts: 1.) pig production and 2.) slaughtering process. Farms from all pig production steps were included and defined by categories (Harris 2000): farrowing (FR), nursery (NF) and finishing (FF). Thirty-five pig farms (33 in North Rhine-Westphalia, Germany and 2 situated in the Netherlands) collaborating with two participating abattoirs (A+B) were enrolled in the study (10 FR, 2 NF and 23 FF). Farrowing farms belong to the breeding production stage. The farrowing sub-stage also includes the farrowing and lactation of the young suckling piglets. The farrowing farms keep piglets up to 1-4 weeks (1.5-8 kg). The farrowing piglets are supplied to nursery farms for rearing the young piglet after weaning (newly weaned pig). Nursery farms raise piglets within the age of 4-12 weeks (8-30 kg) and provide nursery pigs to finishing farms. The finishing period is divided into an early (12-20 weeks, 30-50 kg) and a final finishing period (21-30 weeks, 50-120 kg). The finishing period marks the last step before slaughter. We covered the pig production chain from young farrowing piglet (with no investigation of sows) to the carcasses: young farrowing piglet, farrowing piglet, newly weaned pig, nursery pig, early finishing pig, finishing pig, carcass. The transfer from sows to piglets was not determined.

5.3.2 Farms

The participating farms were recruited for participation in the hygiene monitoring program by their pig producer association. The hygiene monitoring program was an initiative of the pig producer association in collaboration with the agricultural faculty of the University of Bonn. Farms with ≤ 2 pig suppliers were selected for participation. However, it should be noted that it was not compiled if pigs were supplied from one herd to another in the farms included in this study.

The farmers (owners) agreed with the collection of air samples and the sampling of the pigs on the farms. These samples were taken during routine sampling for monitoring and the sampling itself is non-invasive. According to the German animal welfare legislation this study is not an animal experiment. An approval by the regulatory body or an animal welfare committee is not necessary. Nevertheless, all measures taken strictly follow the terms set by the animal welfare committee of the University of Bonn. The data summarized in this study are part of a routine hygiene management monitoring program that was started to provide data on multidrug resistant bacterial colonization in pigs and farm employees and to control measures taken to reduce spread of resistant bacteria. No previous sampling on the colonization status with MRSA and/or ESBL-E was performed. Therefore, no distinction was made between MRSA and/or ESBL-E prevalence in different farm types. No personal data were used or stored for the present study. Therefore, consent from the ethics committee was not required. The owners of the farms and the farm personnel were informed on the program and participated on a voluntary basis. In accordance with the declaration of Helsinki/Seoul written informed consent is available from all human subjects involved. The participating farmers provided the information on the antibiotic classes used on the pigs that were sampled beginning from entry into the farm. This information was verified in their livestock protocols. The results of this study were communicated to the farmers.

5.3.3 Sample collection in pigs

Sample collection was performed from June 2012 to September 2012. From all pigs included in the study we obtained a nasal swab (inserted into both anterior nares) for MRSA screening and an intrarectal swab for ESBL-E detection. Swabs with Amies medium and charcoal were purchased from MAST Diagnostica GmbH, Reinfeld, Germany. Five hundred fifty pigs were sampled; a total of 547 nasal swabs and 540 rectal swabs were analyzed; 3 nasal swabs and 10 rectal swabs did not reach the laboratory.

In the first part of the study, samples were obtained from two age groups housed in two different compartments per farm, i.e. the youngest and oldest age group per farm type: farrowing (young farrowing piglets: 1-2 weeks and farrowing piglets: 2-4 weeks)), nursery (newly weaned pigs: 4-6 weeks and nursery pigs: 9-12 weeks), finishing (early finishing pigs: 12-20 weeks, 30-50 kg and finishing pigs: 21-30 weeks, 50-120kg). Either 10 (farm B1-22) or 5 (farm B23-35) pigs per compartment were screened for MRSA and ESBL-E carriage. Farms were categorized by MRSA/ESBL-E frequencies as follows: Category A: MRSA / ESBL-E free; Category B: > 0 and ≤ 20%; Category C: > 20 and ≤ 50%; Category D: > 50% MRSA/ESBL-E.

In the second part of the study the slaughtering process was subdivided into three sampling periods per pig, e.g. before transport to the abattoir (phase 1), immediately after slaughter (phase 2) and on carcasses in cold storage (phase 3). Transport time from farm to abattoir lay between 1-3 hours. After arrival pigs were separated into an own waiting area in abattoir A or the kept in the common waiting area (in abattoir B) before slaughtering. Thirteen farms selected from the first study period participated. To estimate the risk for contamination with MRSA and/or ESBL-E during the slaughtering process we collected samples from pigs from 7 finishing farms with absent to low (≤ 10%) MRSA and/or ESBL-E in the first sampling period and from 6 farms with higher frequencies (Table S5.6). Samples were collected from three pigs per farm at three different time points: i.) on the farm, ii.) during slaughter (at 2 different abattoirs (A+B) and iii.) on the carcasses deposited in the cool room of abattoir A. At the abattoirs the specimen were taken as described for the farms. All areas defined for swab sampling of swine carcass surfaces according to ISO 17604:2003/Amd.1:2009 were sampled with one swab per carcass. Discordant samples (positive on farm and negative in abattoir) were omitted (2 MRSA, 4 ESBL-E).

5.3.4 Human specimen

Written informed consent was obtained from all participating human volunteers who live or work on the farms. All individuals were categorized as “contact” or “no contact” to pigs and tested for nasal carriage of MRSA and rectal carriage of ESBL-E. Nasal swabs for MRSA were taken from the vestibule of both nares by the responsible physician in the monitoring program; ESBL-E screening was performed from fecal samples in fecal tubes (MAST Diagnostica GmbH), which were delivered by the individuals participating in the monitoring program.

5.3.5 Air samples

The air collection was conducted using an MAS-100 NT® air sampler (Merck KGaA, Darmstadt, Germany). The air was suctioned through a perforated lid (300-x-0.6 mm openings) onto the surface of selective agar plates, e.g. CHROMagarMRSATM for MRSA (n=70) or CHROMagarESBLTM (MAST Diagnostica GmbH) and ESBL (n=67), 30 sec or 10 minutes, respectively. The system used a mass air flow sensor for measuring the air inflow and to maintain the continuous regulation of the air intake volume during sampling. For the detection of ESBL-E, two measurements were performed with an air flow rate of 500 liters/min for five minutes per group. For detection of MRSA, we used an air flow rate of 100 liters/min for one minute (farm B1-22) or thirty seconds (farm B23-35 and abattoirs). The filter system was disinfected with alcohol pads after each measurement (B. Braun Melsungen AG, Melsungen, Germany).

On the farms, air samples were obtained from the center of the compartments 1.20 m above ground level with stable doors closed. At the abattoirs, air samples were collected in the waiting pen (abattoir A+B) and in the cold storage area (only abattoir A).

5.3.6 Bacterial culture

All samples were stored at 4 °C during transport to the laboratory. All specimens were inoculated within 48 hours. All swabs were streaked on Columbia / 5% sheep red blood agar plates (Becton Dickinson, Heidelberg, Germany) and selective agar plates, i.e. CHROMagarMRSA (MAST Diagnostica GmbH) for nasal swabs and CHROMagarESBL (MAST Diagnostica GmbH) for intrarectal swabs and feces. Plates were incubated at 37 ± 1 °C for 24 h. Incubation of air sample plates was started on-site. Sealed plates were incubated for 48 h at 37 ± 1 °C. The colonies were counted as total number of CFU/m3 and reported after statistical correction with the species-specific correction factor (Pr / r) according to Feller (Feller, 1948).

5.3.7 Confirmation of MRSA and *spa* typing

After subculturing on Columbia sheep red blood agar, all presumptive *S. aureus* colonies were checked for hemolysis and confirmed by coagulase testing and MALDI-TOF MS (mass spectrometry) (VITEK MS, bioMérieux SA, Marcy l'Etoile, France). Antibiotic resistance was determined by agar diffusion tests (EUCAST criteria (EUCAST, 2013)) and MRSA confirmed by PBP2a Culture Colony Test (Alere Ltd, Stockport, UK). For each farm, one MRSA isolate per compartment (two per farm: young/old), two air and all human MRSA isolates were typed using *spa*-typing as described in (Harmsen et al. 2003) (148 MRSA isolates from farms and 48 MRSA isolates from abattoirs). Antibiotic resistance was tested by agar diffusion. For isolates with a zone diameter ≥ 16 mm, tetracycline resistance was confirmed by PCR detection of *tetM* and *tetK* (Strommenger et al. 2003).

5.3.8 Identification, antimicrobial susceptibility testing and molecular typing of ESBL-E

All enterobactericeae detected on CHROMagarESBL were identified by MALDI-TOF MS. Antibiotic susceptibility was determined on VITEK-2 (bioMérieux SA) for all non-*E. coli* isolates, two *E. coli* ESBL-E per farm (one per compartment) and all *E. coli* ESBL-E isolates from air, humans and abattoirs. Results were interpreted by EUCAST criteria (EUCAST, 2013). Presence of ESBL genes was confirmed by PCR. DNA was isolated using UltraClean Microbial DNA Isolation Kit (MO BIO Laboratories, Carlsbad, California, USA) and ESBL genes detected by the ESBL Assay from AID GmbH (Straßberg, Germany) using recombinant Taq DNA Polymerase (5U/µl, Thermo Fisher Scientific Inc., Waltham, Massachusetts, USA, #EP0401). AmpC and ESBL positive strains were further confirmed by AmpC&ESBL Detection Discs and Cefpodoxim ESBL ID Disc Set (both from MAST Diagnostica GmbH, Reinfeld, Germany) and ESBL E-Test (bioMérieux SA, Nuertingen, Germany). Molecular typing of *E. coli* strains was performed by repPCR using the Diversilab system (bioMérieux SA) (Naseer and Sundsfjord, 2011). One ESBL-E isolate per farm compartment (2 isolates per farm) and all ESBL-E isolated from air and abattoirs and humans were subjected to DiversiLab analysis. Pulsed field gel electrophoresis (PFGE) was carried out as previously described in (Brolund et al. 2010). In brief, SpeI (New England Biolabs, Marnes-La-Coquette, France) was used for enzymatic digestion of *E. coli* DNA in agar blocks and electrophoresis was performed on a Rotaphor®VI (Biometra GmbH, Göttingen, Germany) for 40 hours (50s log 5s,190 V,130 mA). Analysis was performed using the BioDocAnalyze (BDA) Gel Analysis BDA Software Version 2.66.3.44 9-990-015/English) Version 02/12.

5.3.9 Statistical analysis

The relative risk for ESBL and MRSA double colonization was estimated using the Cochran-Mantel-Haenszel method. Acquisition of MRSA and ESBL-E in the abattoirs were calculated by McNemar test and the differences between abattoirs analyzed by Fisher´s exact test.

5.4 Results

To provide a better overview on colonization and to estimate transmission among pigs and from pigs to the human, we analyzed the frequency of MRSA and ESBL-E in samples obtained from pigs from 35 farms located in the Dutch-German border region as well as two associated abattoirs, the respective farm environment (e.g. air) and persons living and working on these farms (see Figure 5.1 for overview).

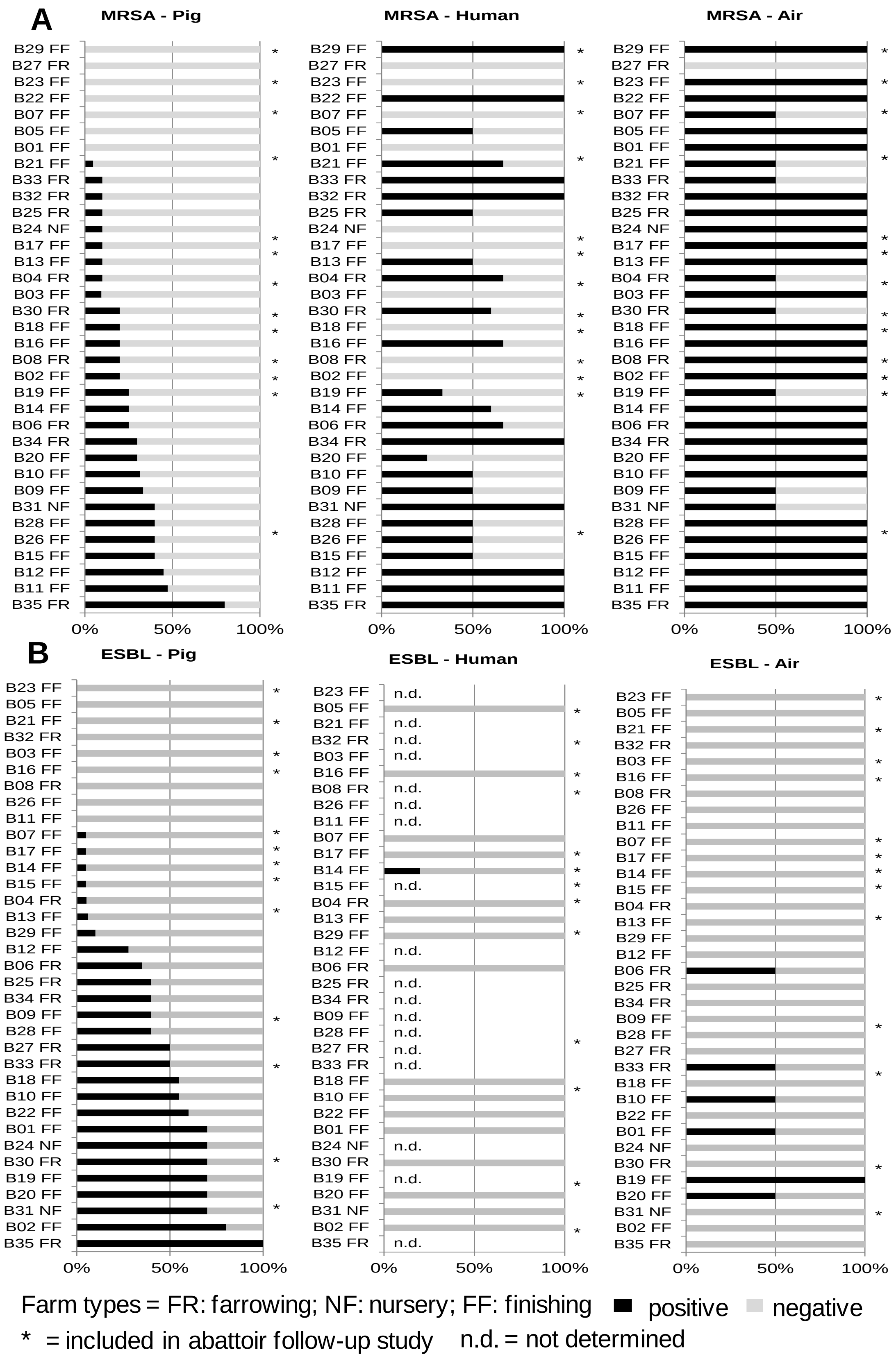


Figure 5.1: ***Comparative overview of MRSA and ESBL-E colonization in pigs, humans and air on farms.***
Samples from pig, human and air were collected on 35 pig farms (B#). Farm types (farrowing (FR), nursery (NF) and finishing (FF)) are provided in the diagram. All samples were

*analyzed for MRSA (**A**) and ESBL-E (**B**). The figure depicts the results obtained on the individual farms sorted by prevalence of MRSA (**A**) or ESBL-E (**B**), respectively. Bars depict the percentage of positive (black) and negative (gray) samples.*

5.4.1 Prevalence of MRSA and ESBL-E in pigs

MRSA was detectable in 20.7% of pigs and ESBL-E in 30.2% of pigs (Figure 5.2A). Thus, ESBL-E frequency was 32% higher than MRSA colonization. The majority of recovered ESBL-E were *Escherichia coli* isolates (95.1%). Next to *E. coli* we detected 7 *Citrobacter* spp. and one *Serratia fonticola* ESBL-E as well as two *Enterobacter cloacae* isolates, which were disregarded in the subsequent analyses. Double colonization with MRSA and ESBL-E was detected in 8.9% pigs on 17 farms. This corresponds to 42.5% of MRSA positive pigs and 29.5% of ESBL-E colonized pigs. Overall, MRSA colonization correlated with ESBL-E recovery and vice versa (RR = 3.25 CI [1.84-5.73]).

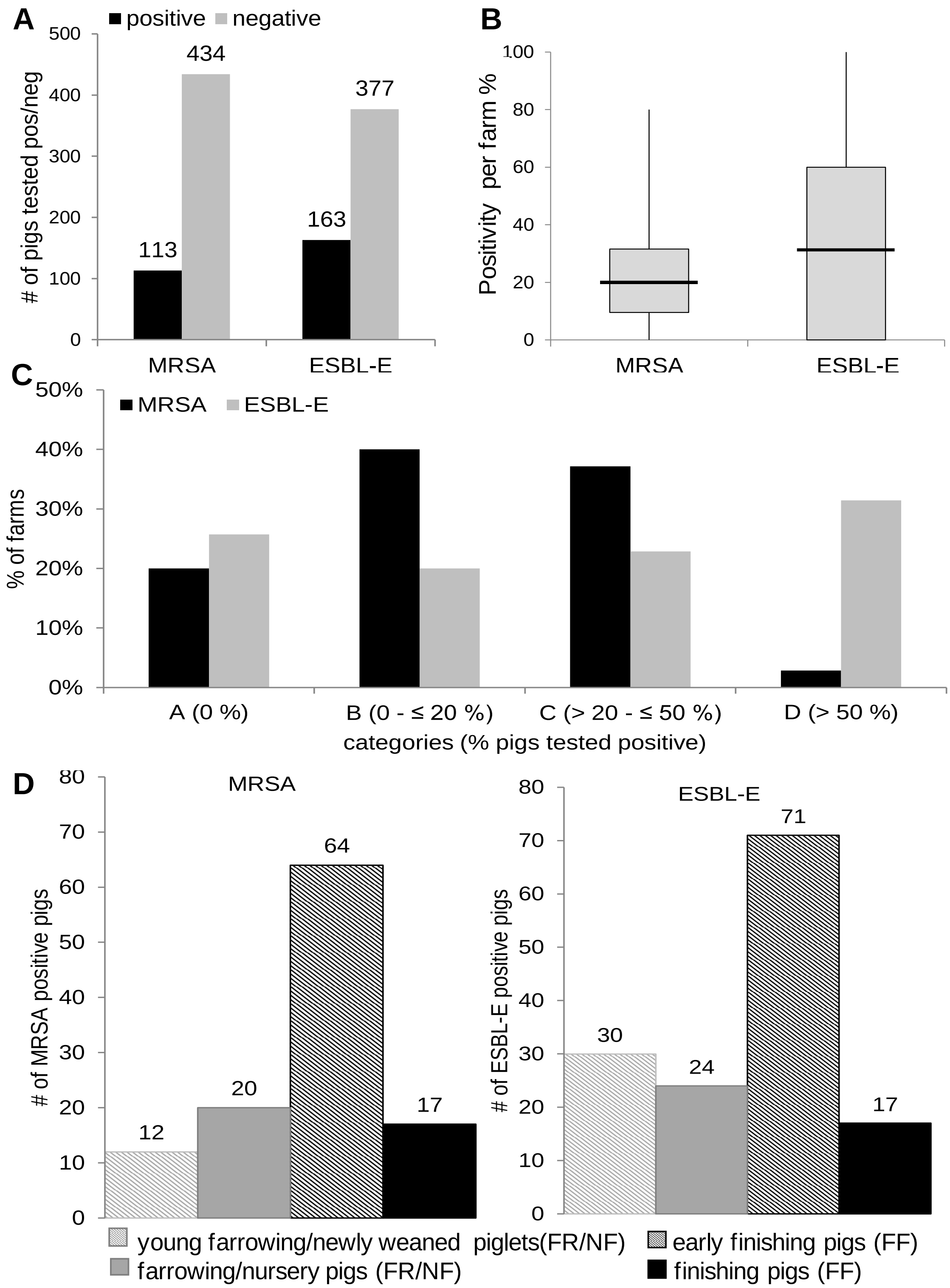


Figure 5.2: ***MRSA and ESBL-E recovery in pig samples.***
A: *Summary of results obtained in all tested pigs. The graph depicts the absolute numbers of pigs tested positive (black bars) or negative (gray bars) for MRSA and ESBL-E.* ***B:*** *The graph depicts the range (boxplots) of colonization (in %) for MRSA (left) and ESBL-E (right) on farms. The median is indicated as a black line.* ***C:*** *Farms were categorized based on their MRSA (black bars) and ESBL-E (gray bars) colonization. Four categories (A to D) were*

defined as indicated in the diagram. ***D:*** *Number of MRSA (left) and ESBL-E (right) positive pigs in different pig production steps and farm types (farrowing (FR) and nursery (NF) farms compared to finishing (FF) farms). Production steps within these farm types are categorized as young farrowing/newly weaned piglets (gray hatched bars) and farrowing/nursery pigs (gray bars) in FR/NF and early finishing (black hatched bars) and finishing pigs (black bars) in FF.*

5.4.2 Frequency of MRSA and ESBL-E colonized farms

Analysis of MRSA and ESBL-E positivity on the farm level revealed that there were more farms with MRSA detection (80% of farms) than farms with ESBL-E recovery (74.3%) (Figure 5.1A+B). Only two farms were free of MRSA and ESBL-E and 60.0% had pigs colonized with both.

MRSA colonization ranged from 0-80% of tested pigs on a farm (median: 20%) (Figure 5.2B; Table S5.1). As shown in Figure 5.2C, 20.0% of farms were MRSA-free, e.g. Category A, 40% Category B, 37.1% Category C, 2.9% Category D. By contrast, analysis of ESBL-E detection revealed that a higher percentage of farms was ESBL-E free (25.7%; Category A) (Figure 5.2C). However, ESBL-E detection ranged from 0-100% (Median: 35%) (Figure 5.2B; Table S5.2) and positivity within an affected farm was higher than with MRSA, e.g. 31.4% of farms belonged to Category D, 22.9% to Category C and only 20% Category B.

5.4.3 MRSA and ESBL-E colonization varies depending on the pig production level

In each farm we collected samples from two compartments, e.g. youngest and oldest pigs. In the farrowing and nursery step we defined the young pigs as “young farrowing/newly weaned” and the older pigs as “farrowing/nursery pigs”. In the finishing step we defined the young pigs as “early finishing” and the older ones as “finishing pig”. Notably, MRSA and ESBL-E colonization frequency varied depending on the pig production level (Figure 5.2D, Table S5.3, Table S5.4). Piglets with MRSA and ESBL-E colonization were found on both nursery farms (100%); on farrowing farms MRSA was present on 9/10 (90.0%) and ESBL-E on 8/10 (80.0%) farms. The overall prevalence of MRSA and ESBL-E isolated from pigs was lower on finishing farms, i.e. 73.9% and 69.6%, respectively.

Further analyses revealed age-dependent differences in MRSA colonization frequencies (Figure 5.2D; Table S5.3): in farrowing and nursery farms the MRSA positivity was 21.3%; 62.5% of these MRSA were isolated from farrowing/nursery pigs and only 37.5% were detected in young farrowing/newly weaned piglets. This was also reflected on a farm level, e.g. in 10/12 (83.3%) farms MRSA detection in farrowing/nursery pigs was ≥ 10% and only 2/12 (16.7%) were below 10%. Global MRSA frequencies in finishing farms were comparable to those in farrowing farms, e.g. 19.8%. On a farm level 16/23 (69.6%) of finishing farms had MRSA frequencies of ≥ 10% and only 7/23 (30.4%) were < 10%. However, further analyses revealed a statistically significant difference between MRSA frequencies in early finishing pigs (79%) compared to finishing pigs (20.9%) ($p < 0.001$). Taken together these data indicate that farrowing/nursery pigs and early finishing pigs are most prone to be colonized with MRSA.

The overall ESBL-E frequency in farrowing and nursery farms was 36.0%. A higher prevalence was found in young farrowing/newly weaned piglets (55.6%) compared to farrowing/nursery pigs (44.4%) (5.2D;

Table S5.4). On the farm level, ESBL positivity ≥ 10% was found in 10/12 (83.3%) “young farrowing/newly weaned” compartments and in 8/12 (66.7%) “farrowing/nursery” compartments. In finishing farms the ESBL-E positivity was lower, e.g. 26.6%. Early finishing pigs accounted for 65.1% of positive ESBL-E and only 34.9% were detected in finishing pigs. This difference was statistically significant ($p < 0.0001$). Analysis on a farm level showed that the ESBL-E detection in “early finishing” compartments was ≥ 10% on 14/23 finishing farms (60.9%). In “finishing” compartments 43.5% (10/23) farms displayed ESBL frequencies ≥ 10% and 56.5% (13/23) farms lay below 10%.

5.4.4 MRSA and ESBL-E detection in humans working and living in the farm environment

The recent spread of LA-MRSA strains in the population could reflect a transmission from pigs to humans. 48.8% (42/86) of samples from farmers, staff and family were tested positive for MRSA (Table S5.5). On 21 farms MRSA was recovered on both pigs and humans.

Of those tested positive only one person had no contact to pigs; in those individuals with no direct contact to pigs all but one person were MRSA negative. Persons who regularly came in contact with pigs were more frequently colonized with MRSA when compared to those with no contact, e.g. 53.2% (42/79). Thus, contact to pigs was associated with increased MRSA colonization. Notably, the MRSA frequency in individuals who had no contact was higher than in the general German population (Anwar et al. 2004; Köck et al. 2011) despite the inaccuracy due to the low sample numbers.

Fecal swabs from all individuals tested were positive for ESBL-E in 2.5% (1/40). The person with ESBL-E colonization was negative for MRSA but colonized with an MSSA (t005). This person had no contact to pigs but regular contact to the healthcare system. Altogether, colonization with ESBL-E was less frequent than that with MRSA.

5.4.5 MRSA and ESBL-E transmission in the slaughtering process

Pigs from farms with high MRSA and ESBL-E colonization might represent a risk for a carry-in of multidrug resistant bacteria into the slaughtering process. Thus, we screened for MRSA and ESBL-E carriage in pigs before and after delivery to the abattoir and on the carcasses. Statistically significant acquisition of MRSA or ESBL-E in pigs tested negative before arrival at the abattoirs was observed in 29.7% ($p=0.001$) and 29.4% ($p \leq 0.05$), respectively (Table S5.6).

It is noteworthy that we observed differences in acquisition of MRSA and ESBL-E in pigs between abattoirs. The increases in MRSA and ESBL-E detection were as follows: abattoir A: MRSA 18.8% (3/16; not significant), ESBL-E 8.3% (1/12; not significant); abattoir B: MRSA 38.1% (8/21; $p \leq 0.001$); ESBL-E 40.9% (9/22; $p = 0.02$). The difference between abattoirs was statistically significant for MRSA ($p=0.04$). This discrepancy might be attributed to handling of pigs until slaughtering, e.g. there was a separated and dry waiting area in abattoir A, while pigs were randomly mixed and irrigated in abattoir B. Altogether, these data allow the conclusion that transmission of MRSA and ESBL-E among pigs during transport and the waiting period at the abattoir might occur with nearly 30% probability. Waiting conditions such as irrigation might influence the likelihood of transmission. Nevertheless, there was no detection of MRSA or ESBL-E on the carcasses of the tested pigs.

5.4.6 Evaluation of air as transmission medium

It has previously been proposed that air might serve as an important transmission medium in pig holdings (Friese et al. 2012). To correlate MRSA and ESBL-E content in air with pig and human colonization we analyzed air samples collected by impaction (Table S5.7). Samples were obtained in all stable compartments where pigs were sampled. MRSA were detected in the stable air of 34 out of 35 (97.1%) pig farms tested (i. e. ≥ 1 out of 2 samples positive). On 74.3% of farms MRSA were detected in air samples from both compartments and in 22.9% of farms only one compartment (young/old) was contaminated. There was no difference between farrowing/nursery and finishing farms.

Notably, air samples from one farm were completely free of MRSA (B27). This farm was also classified as Category A in pig sampling. On three farms MRSA was detected in the air but was absent in the samples obtained from pigs and humans.

ESBL-E positive air samples were found on 17.1% of investigated pig farms. All of these farms were affected by both ESBL-E and MRSA colonization in pigs (ESBL-E Categories: C (1 farm), D (5 farms) and MRSA Categories A (1 farm), B (1 farm), C (4 farms)). Comparative analysis of farrowing/nursery versus finishing farms displayed no relevant difference in air positivity related to the pig production level, e.g. 16.7% and 17.4%, respectively.

Air sampling in the abattoirs delivered the following results: the MRSA frequency was comparable to that in the air samples obtained on farms, e.g. 13/14 (92.9%). However, the ESBL-E frequency was higher than on farms, e.g. 6/12 (50.0%). Due to the low sample numbers obtained in the abattoirs we decided against performing a statistical comparison of farms and abattoirs; the trend, however, was clear. Notably, no relevant differences were found in the comparison of abattoirs (Table S5.8). Collectively these data indicate that MRSA contamination of air is more wide-spread than for ESBL-E. However, there was no correlation of ESBL-E detection in air with that in humans.

5.4.7 Antimicrobial susceptibility testing of MRSA isolates

LA-MRSA strains belong to the ST398 lineage and are characterized by tetracycline resistance (Graveland et al. 2011a; Köck et al. 2009; Wagenaar et al. 2009). All 196 strains tested were resistant to penicillin and cefoxitin. By agar diffusion testing 191/196 (97.4%) of isolates were further resistant to doxycycline, a characteristic of LA-MRSA. We confirmed tetracycline resistance in isolates with zone diameters ≥ 16 mm via presence of *tetM* (2 isolates) or *tetK* (1 isolate) resistance genes.

5.4.8 Molecular typing of MRSA

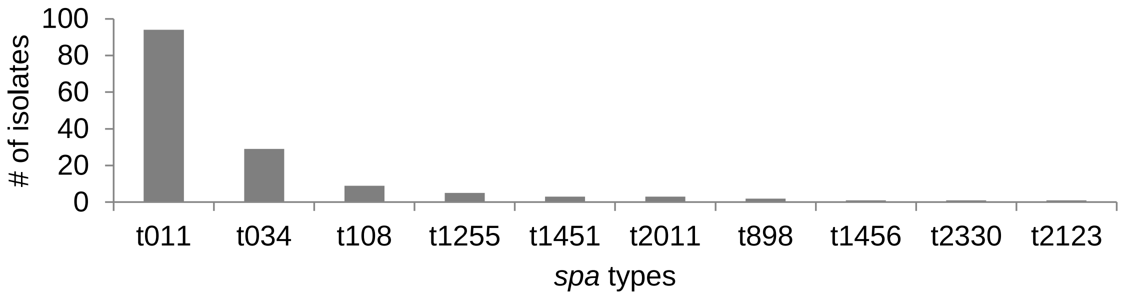
To confirm the LA-MRSA lineage of the isolates we performed *spa* typing (Figure 5.3A). The *spa* types most frequently isolated from snouts and air were t011 (n=130) and t034 (n=35) (Figure 5.3B; Table

S5.9). Highlighting its transmission potential, all MRSA *spa* types belonged to the ST398 lineage. Only two MSSA isolates recovered from human nasal swabs corresponded to *spa* types t005 and t491 that do not belong to this lineage.

A

MRSA *spa* types			
***spa* type**	**repeats**	**# in farms**	**# in abattoirs**
t011	08-16-02-25-34-24-25	95	35
t034	08-16-02-25-02-25-34-24-25	28	7
t108	08-16-02-25-24-25	9	2
t1255	08-16-34-24-25	5	0
t2011	08-16-16-02-25-34-24-25	3	1
t1451	08-16-02-25-34-25	3	1
t898	08-16-02-25-02-25-34-34-24-25	2	0
t2330	08-16-02-25-34-24-25-25	1	0
t2123	08-25	1	0
t1456	08-16-02-25	1	0
t2346	08-16-02-25-34-24-24-25	0	1
t1197	08-16-02-25-46-24-25	0	1
Total		148	48

B



C

Recovery in pig, human, air	**# of isolates per *spa* type**									
	t011	**t034**	**t108**	**t125**	**t1451**	**t1456**	**t2011**	**t2330**	**t2123**	**t898**
All 3	12	2	0	1	0	0	0	0	0	0
Pig Air	6	3	0	0	1	0	1	0	0	0
Human Air	5	1	0	0	0	0	0	0	0	0
Pig Human	1	1	0	0	0	0	0	0	0	0
Pig only	1	1	0	0	0	1	0	0	0	0
Human only	4	2	0	1	0	0	1	0	0	0
Air only	3	4	0	0	0	0	0	0	0	0

Figure 5.3: ***spa typing of MRSA isolates.***
A: *spa types of MRSA isolates obtained from pigs, human and air.* ***B:*** *Prevalence of spa types detected on farms and on abattoirs.* ***C:*** *Analysis of spa types in regard to their simultaneous presence in different media (pig, human, air).*

The *spa* type t011 was found in 32/35 participating farms (91.4%); t034 was detected on 20/35 farms (57.1%) and t108 on 6/35 farms (17.1%). In 12 out of 35 farms (34.3%) t011 was found in pigs, humans and air (Figure 5.3C). This was also observed with t034 (B04, B09) and t1255 (B30) (Table S5.9). In additional 6 of 35 farms (17.1%) t011 was detected in humans and air but not in pigs. No relevant differences in *spa* type distribution were found between abattoir and farm and between air, pigs and humans. However, *spa* types t2346 and t1197 were only recovered from abattoir B, possibly indicating transmission from pigs from other farms.

5.4.9 Analysis of ESBL enzymes reveals predominance of CTX-M

The presence of ESBL genes was confirmed by PCR analysis. We detected ESBL enzymes in 69 of 72 third generation cephalosporin resistant *E. coli* strains, thus, proving the high specificity of the medium used for ESBL-E selection (Grohs et al. 2013); two isolates were AmpC positive. The majority of *E.coli* ESBL-E isolates, i.e. 95.7 %, were CTX-M positive as reported previously in (Blanc et al. 2006; Cavaco et al. 2008; Hammerum et al. 2014; Horton et al. 2011; Hu et al. 2013; Liu et al. 2013; Tian et al. 2009). One isolate was CTX-M and TEM AS 238 S, one was SHV AS 238/240 and another isolate was TEM AS 238 S and TEM AS 104 K.

5.4.10 Rep-PCR-typing of ESBL-E isolates reveals heterogeneity of ESBL-E

To assess whether the *E. coli* ESBL-E strains isolated arose from a common strain we performed a repetitive element PCR (rep-PCR) analysis of the purified DNA samples using the DiversiLab system. This method offers a rapid and automated method for genotyping with high reproducibility and the important advantage of an electronic database. Cut-off values were set at 98% similarity to increase the discriminatory power of the method (Brolund et al. 2010; Deplano et al. 2011; Voets et al. 2012).

The results obtained revealed genetic heterogeneity of strains among the different farms (Figure 5.4A). However, a few clusters with high similarity (≥ 98%) composed of isolates from different farms were also detected (Figure 5.4B). The isolates within these clusters were subjected to PFGE analysis, which confirmed strain relatedness in some but not all cases. The results are shown in Figure 5.4C.

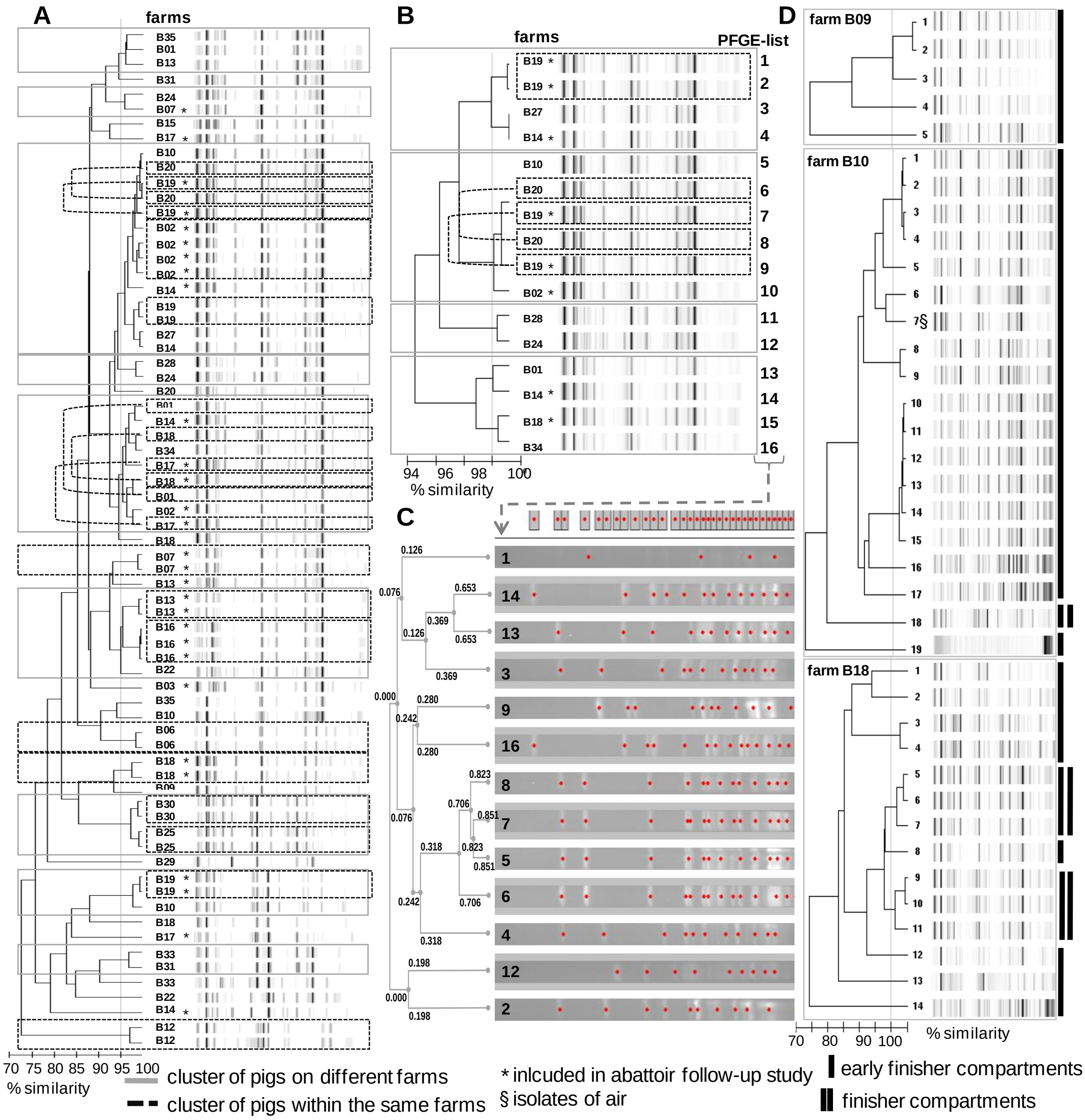


Figure 5.4: ***Molecular typing of E. coli ESBL-E isolates.***
*Representative ESBL-E isolates from pigs, air and human were analyzed by repPCR (Diversilab, Biomerieux, Nürtingen, Germany) (**A**, **B** and **D**) or pulsed field gel electrophoresis (PFGE) (**C**). **A, B and D:** Diversilab typing results. Clusters of isolates obtained from different farms are marked by gray rectangles and clusters of isolates from pigs derived from the same farm are marked by black hatched lines. **A:** Overview of Diversilab typing results of representative ESBL-E isolates. The cut-off value was set at 95% similarity. **B and C:** To confirm strain relatedness all ESBL-E isolates from clusters with a similarity of ≥ 98% (summarized in **(B)**) were reanalyzed by pulsed field gel electrophoresis (PFGE) **(C)**. **D:** On three exemplary farms with high ESBL-E prevalence (B09, B10, B18) all ESBL-E isolates from the same farm were subjected to Diversilab analysis to test for strain relatedness within the farm and/or a single compartment. Isolates from early finishing compartments are marked by black lines and those from finishing compartments by double black lines. Isolates from air are indicated by a "§".*

Notably, strain relatedness was found in simultaneously collected isolates from air and pigs (Figure 5.4A) but isolates obtained at the abattoirs did not necessarily match with those collected on the farms (Figure 5.4A+B).

Not surprisingly, among the clusters with ≥ 98% similarity there also were pairings of isolates originating from the same farm (Figure 5.4A+B), which were confirmed by PFGE (Figure 5.4C). To better define the strain-relatedness within a single farm and a farm compartment (young versus old pigs) we chose three farms with a high number of ESBL-E isolates (B09, B10, B18) for a more detailed analysis (Figure 5.4D). If more than one morphologically distinct ESBL-E was found on a pig we included both isolates. The findings obtained revealed that despite individual clusters with high (≥ 98%) similarity we mostly detected unrelated *E. coli* isolates within one farm (< 95% similarity) (Figure 5.4D). Furthermore, similarity between isolates from the young and old compartments in B10 and B18 was < 95% (Figure 5.4D). Clusters with ≥ 95% similarity were usually derived from the same compartment but even within the individual compartment many isolates were unrelated (< 95% similarity) (Figure 5.4D).

5.4.11 Usage of antibiotics on farms

Finally, we asked whether the colonization with drug resistant bacteria might reflect the therapeutic usage of antibiotics on the farms. Our analysis showed that betalactam antibiotics are most frequently administered, thus providing the selective pressure that allows the emergence of MRSA and ESBL-E (Figure 5.5A). Moreover, high usage of tetracyclines can account for selection of tetracycline-resistant strains. Indeed, nearly 100% of MRSA isolates displayed resistance to tetracyclines (Figure 5.5B) and ESBL-E were resistant to tetracycline in 59.2% and to doxycycline in 58.7% (Figure 5.5C).

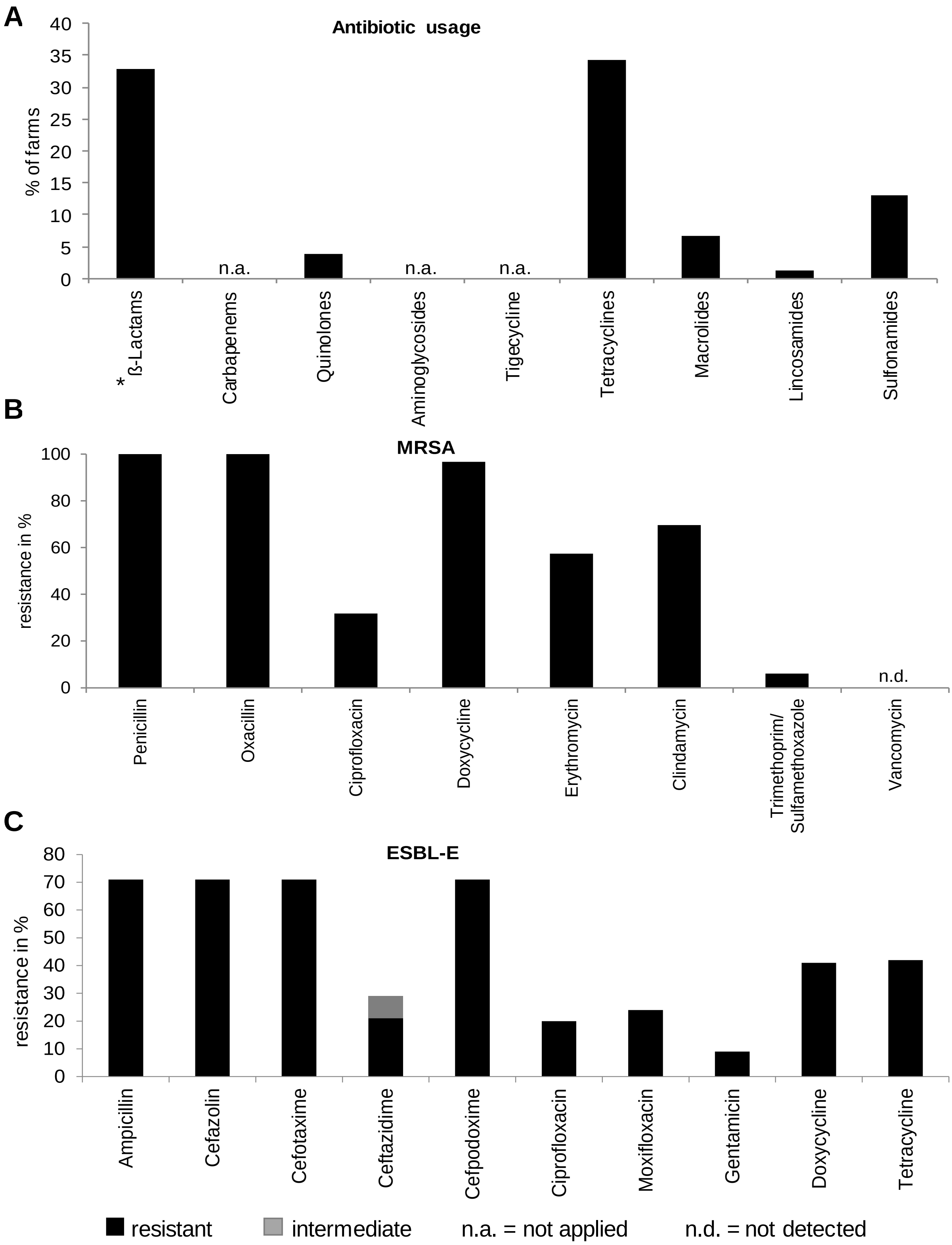


Figure 5.5: ***Comparison of antibiotic usage and antibiotic resistance patterns on farms.***
A: *Antibiotic substances administered on investigated farms. (*) Betalactams comprise ampicillin, amoxicillin, other penicillins and cephalosporins. Carbapenems, aminoglycosides and tigecycline were not applied (n.a.).* ***B:*** *Susceptibility of spa typed MRSA isolates obtained on farms given as % resistant.* ***C:*** *Susceptibility of tested ESBL-E isolates is provided as % resistant.*

By contrast, use of other antibiotic substances was restricted to a smaller number of farms, e.g. macrolides (5 farms), lincosamides (1 farm), quinolones (3 farms) and sulfonamides (10 farms) (Figure 5.5A). Nevertheless, antimicrobial susceptibility testing of MRSA revealed resistance to all substances used by the farmers, i.e. erythromycin in 57.7% isolates, clindamycin in 76.0% isolates, ciprofloxacin in 30.6% isolates and to combined trimethoprim/sulfomethoxazole in 5.1% isolates (Figure 5.5B). All MRSA isolates tested were susceptible to vancomycin. Notably, strains resistant to macrolides, lincosamides and quinolones were found independent of the use of these antibiotic substances on the individual farm.

In ESBL-E we detected resistance to quinolones (ciprofloxacin 28.2%, moxifloxacin 33%) while resistance to carbapenems or combined trimethoprim/sulfomethoxazole was not observed (Figure 5.5C). Again, quinolone resistance did not predict use of these antibiotics.

5.5 Discussion

Livestock serves as an important reservoir for transferable resistance genes (Broens et al. 2011b; Marshall and Levy 2011; Smith et al. 2002). To our knowledge this study is the first to demonstrate co-colonization with MRSA and ESBL-E on the individual animal (Figure 5.1). Albeit not astonishing, on the farm level pigs colonized with MRSA were likely to be colonized with ESBL-E and vice versa, thus, indicating that farm-dependent factors including the amount and class of antibiotics in use foster the selection of drug-resistant pathogens. In support of this hypothesis we further recovered strains resistant to all other antibiotic classes presently in use on the participating pig farms (Figure 5.5A).

This was further supported by the finding that both MRSA and ESBL-E colonization frequencies varied depending on the pig production level (Figure 5.2D, Table S5.3, Table S5.4) (Broens et al. 2011b; Friese et al. 2012; Friese et al. 2013; Hansen et al. 2013; van der Fels-Klerx et al. 2011). Higher MRSA colonization in the finishing compartments (Figure 5.2D, Table S5.3) correlated with previous exposure to antibiotics, which is usually highest at the early stages of breeding (piglets) (Khanna et al. 2008). As described in earlier studies both ESBL-E and MRSA detection declined at the ready-to-slaughter stage (Figure 5.2D, Table S5.3, Table S5.4) (Escudero et al. 2010; Smith et al. 2009) which might reflect restricted antibiotic usage at this production level (Callens et al. 2012; MARAN 2009).

It is, however, a current matter of debate whether antibiotic consumption in the veterinary field is responsible for the spread of drug-resistant bacteria among farm animals. In the present study frequent usage of betalactam antibiotics on the participating farms (Figure 5.5A) was well in line with the presence of bacterial strains resistant to betalactams, i.e. MRSA and ESBL-E, in the pigs. However, antibiotic susceptibility patterns on the individual farms did not correlate with the antibiotics in use on the respective farms (data not shown), which highlights the complexity of this issue.

The present study confirms earlier results that suggest transmission of MRSA from pigs to humans and vice versa (Broens et al. 2012; Cuny et al. 2009; Graveland et al. 2011a; Graveland et al. 2011b; Khanna et al. 2008; Meemken et al. 2008). Moreover, a recent study observed transmission of IncN plasmids harbouring ***bla***$_{\text{CTX-M-1}}$ between commensal *E. coli* of pigs and commensal *E. coli* in humans in Denmark (Moodley and Guardabassi 2009). However, there is no evidence for ESBL-E colonization of humans in our farm collective as also reported in (Carattoli 2008). While this could be due to differences in the hygiene regimes employed by farms from different countries, our data further indicate that MRSA transmission might be facilitated by its almost ubiquitous presence in air (Figure 5.1A, Table S5.7, Table S5.8). An earlier study by (Friese et al. 2012) supports our observations and highlighted stable air as an ideal transmission medium for MRSA (Schulz et al. 2012). Nevertheless, MRSA recovery from impaction samples did not predict MRSA colonization of pigs (Figure 5.3C). However, we observed MRSA transmission in the abattoirs, which supports earlier findings suggesting that transmission can occur within a short time frame, i.e. in less than two hours (Broens et al. 2011a; Broens et al. 2011b; de Neeling et al. 2007; Huletsky et al. 2005; Tenhagen et al. 2009).

In contrast to MRSA, ESBL-E was only rarely detected in air samples (Table S5.7, Table S5.8). However, ESBL-E detection in impaction samples was always associated with ESBL-E colonization of pigs in the respective farm (Figure 5.1B). Since humidity is required for persistence of enterobacteriaceae on inanimate surfaces, we further reasoned that the lower presence of ESBL-E in air samples could be due to low humidity in stable air. Well in line with this hypothesis, ESBL-E was detected in 6 of 12 (50%) of air samples in the abattoirs that are kept at higher air humidity (Table S5.8) compared to only 6 of 67 (9%) of air samples on farms that have normal environmental humidity (Table S5.7). From a technical point of view, future work will have to verify whether impaction is, indeed, superior to impingement in regards to recovery of ESBL-E under normal environmental humidity conditions as suggested for *Salmonella* spp. in (Adell et al. 2014; Hurd et al. 2001; Hurd et al. 2002).

Furthermore, ESBL-E transmission was detected in the abattoirs and was higher in abattoir B where pigs were held in a humid environment until slaughtering (Table S5.6, Table S5.8). Although we need to take into consideration that the screening methods used might have failed to detect ESBL-E (and MRSA) in the pigs before delivery to the abattoir, it should be denoted that recent studies have postulated that transmission of *Salmonella* spp. in pigs is fostered by humidity in the abattoir waiting area (Hurd et al. 2001; Hurd et al. 2002). Thus, the risk for ESBL-E transmission is probably higher in the abattoirs than on the farms and during transport. Our future studies will, therefore, clarify whether employees working in abattoirs face a higher risk of ESBL-E transmission through pig contact than those working on farms (Escudero et al. 2010).

Colonization of livestock with drug resistant bacteria is often considered a risk factor for meat contamination with resistant bacteria (Tenhagen et al. 2009). As proposed by earlier studies, colonization of pigs did not result in contamination of carcasses kept in the cool room of the abattoir after slaughter with MRSA and ESBL-E (Table S5.6) (Beneke et al. 2011; Kastrup 2011). This was not surprising because the muscle itself is sterile and the meat production involves strict hygiene measures including mechanical cleansing of the carcass and a series of heat exposures that destroys the microflora. In the present cases, the multi-step procedure included a 60°C hot water treatment and repeated exposures to 2000°C in ovens optimized to reach 100°C within the carcass, i.e. sterilizing conditions. We, therefore, postulate that the risk for contamination of meat is much higher than during processing of the carcasses.

Several studies have identified MRSA lineages that are prototypically found in pigs (Broens et al. 2011b; de Neeling et al. 2007; Friese et al. 2012; Köck et al. 2009; Tenhagen et al. 2009). Not surprisingly, as seen in our study these strains are usually resistant to tetracyclines (Figure 5.5B), another class of antibiotics frequently employed in livestock (Figure 5.6A) (Callens et al. 2012). They have further identified the molecular changes that occur in LA-MRSA upon adaptation to the human host (Harrison et al. 2013; Price et al. 2012). Our study highlights the predominance of LA-MRSA associated *spa* types in pigs and humans with direct contacts to pigs and their family members (Figure 5.3C; Table S5.5). Altogether, the findings indicated that selective pressure by antibiotics might favor the spread of defined (LA-)MRSA strains among pigs and from pigs to humans or vice versa.

Similarly, specific ESBL resistance genes such as certain CTX-M subgroups have been found with high homogenity within pig herds (Blanc et al. 2006; Escudero et al. 2010; Tian et al. 2009). It has further been proposed that defined *E. coli* strains acquired ESBL resistance genes and spread among pigs (Gonçalves et al. 2010). In the present study molecular typing was performed using a rep-PCR method. The results obtained revealed high diversity of *E. coli* ESBL-E isolates (< 95% similarity by DiversiLab typing) when comparing isolates from different farms (Figure 5.4A). Only small clusters of strains with ≥ 98% similarity revealed a potential spread of strains beyond the individual farm (Figure 5.4B). What is more, genetic heterogeneity of *E. coli* isolates was high, even among strains collected from pigs within the same compartment. This lead to the hypothesis, that ESBL resistance is not transmitted by individual strains, i.e. counterparts of LA-MRSA. It must rather be assumed that selective pressure exerted by antibiotics fosters spread of defined molecular resistance mechanisms and their horizontal transfer within the pre-existing *E. coli* population present in the intestinal microflora.

It has been postulated that CTX-M enzymes are derived of chromosomal betalactamases of *Klyuvera* spp. that spread to enterobactericeae on resistance plasmids (Cantón and Coque 2006). Reasoning that administration of antibiotics might induce ESBL expression in a pre-existent small but stable pool of colonizing enterobacteriaceae, we figured that it is possible that these conjugative ESBL plasmids represent an advantage for spread when compared to transmission of LA-MRSA strains. Indeed, spread of ESBL-E within a compartment was more complete than that of MRSA, e.g. once ESBL-E was detected on a farm it normally affected nearly all pigs present within the compartment tested (Table S5.3, Table S5.4). By contrast, MRSA colonization rarely affected all pigs within one compartment (Table S5.3) although total MRSA colonization was higher than the ESBL-E detection (Table S5.4). This suggested that within the compartment ESBL-E is either more rapidly transmissed, ESBL-E colonization is more stable or culture methods used for enrichment were more sensitive for ESBL-E than for LA-MRSA.

Our study results further suggested that, on the contrary to the results obtained on the farms, acquisition of MRSA by the individual pig in the abattoir was more frequent than that of ESBL-E (Table S5.6). While antibiotic selection of ESBL-E in the intestine may account for ESBL carriage on the farms, close animal contact in the waiting bay of the abattoir may favour the rapid spread of MRSA. This demonstrates that transmission of resistant bacteria as well as resistance determinants in the pig production chain may vary depending on the environment, antibiotic exposure and bacterial species.

5.6 Acknowledgments

We thank all farmers and their families and employees for participating in this study. We thank the abattoirs for their cooperation and trust. We thank André Christ for providing help with statistics, figures and excel files. We are indebted to I. Schulze-Geisthövel, Drensteinfurt, Germany, T. Klauke and P. Heinrich, Bonn, Germany for active support during all sampling periods and organizational support, respectively.

5.7 Supporting Information

Table S5.1: MRSA and ESBL-E colonization in pigs (sorted by MRSA prevalence on farms).

	Pig - MRSA			Pig - ESBL-E		
Farms	negative	positive	% pos	negative	positive	% pos
B35 FR	2	8	80%	0	7	100%
B11 FF	10	9	47%	20	0	0%
B12 FF	11	9	45%	13	5	28%
B15 FF	12	8	40%	19	1	5%
B26 FF	6	4	40%	10	0	0%
B28 FF	6	4	40%	6	4	40%
B31 NF	6	4	40%	3	7	70%
B09 FF	12	6	33%	12	8	40%
B10 FF	13	6	32%	9	11	55%
B20 FF	14	6	30%	6	14	70%
B34 FR	7	3	30%	6	4	40%
B06 FR	15	5	25%	13	7	35%
B14 FF	15	5	25%	19	1	5%
B19 FF	15	5	25%	6	14	70%
B02 FF	16	4	20%	4	16	80%
B08 FR	16	4	20%	19	0	0%
B16 FF	16	4	20%	20	0	0%
B18 FF	16	4	20%	9	11	55%
B30 FR	8	2	20%	3	7	70%
B03 FF	19	2	10%	20	0	0%
B04 FR	18	2	10%	18	1	5%
B13 FF	18	2	10%	16	1	6%
B17 FF	18	2	10%	19	1	5%
B24 NF	9	1	10%	3	7	70%
B25 FR	9	1	10%	6	4	40%
B32 FR	9	1	10%	10	0	0%
B33 FR	9	1	10%	5	5	50%
B21 FF	20	1	5%	20	0	0%
B01 FF	20	0	0%	6	14	70%
B05 FF	10	0	0%	10	0	0%
B07 FF	19	0	0%	19	1	5%
B22 FF	10	0	0%	4	6	60%
B23 FF	10	0	0%	10	0	0%
B27 FR	10	0	0%	5	5	50%
B29 FF	10	0	0%	9	1	10%

FR = farrowing, NF = nursery, FF = finishing

Table S5.2: MRSA and ESBL-E colonization in pigs (sorted by ESBL-E prevalence on farms).

	Pig - ESBL-E			Pig - MRSA		
Farms	negative	positive	% pos	negative	positive	% pos
B35 FR	0	7	100%	2	8	80%
B02 FF	4	16	80%	16	4	20%
B31 NF	3	7	70%	6	4	40%
B20 FF	6	14	70%	14	6	30%
B19 FF	6	14	70%	15	5	25%
B30 FR	3	7	70%	8	2	20%
B24 NF	3	7	70%	9	1	10%
B01 FF	6	14	70%	20	0	0%
B22 FF	4	6	60%	10	0	0%
B10 FF	9	11	55%	13	6	32%
B18 FF	9	11	55%	16	4	20%
B33 FR	5	5	50%	9	1	10%
B27 FR	5	5	50%	10	0	0%
B28 FF	6	4	40%	6	4	40%
B09 FF	12	8	40%	12	6	33%
B34 FR	6	4	40%	7	3	30%
B25 FR	6	4	40%	9	1	10%
B06 FR	13	7	35%	15	5	25%
B12 FF	13	5	28%	11	9	45%
B29 FF	9	1	10%	10	0	0%
B13 FF	16	1	6%	18	2	10%
B04 FR	18	1	5%	18	2	10%
B15 FF	19	1	5%	12	8	40%
B14 FF	19	1	5%	15	5	25%
B17 FF	19	1	5%	18	2	10%
B07 FF	19	1	5%	19	0	0%
B11 FF	20	0	0%	10	9	47%
B26 FF	10	0	0%	6	4	40%
B08 FR	19	0	0%	16	4	20%
B16 FF	20	0	0%	16	4	20%
B03 FF	20	0	0%	19	2	10%
B32 FR	10	0	0%	9	1	10%
B21 FF	20	0	0%	20	1	5%
B05 FF	10	0	0%	10	0	0%
B23 FF	10	0	0%	10	0	0%

FR = farrowing, NR = nursery, FF = finishing

Table S5.3: MRSA colonization in pigs (sorted by age and production step).

	Pigs		Pig - MRSA		Pig - MRSA		
Farm	% pos	comp	young far./ newly we.	farrowing/ nursery	young far./ newly we.	farrowing/ nursery	**Type**
B35 FR	80%	5	3	5	60%	100%	FR
B34 FR	30%	5	1	2	20%	40%	
B06 FR	25%	10	2	3	20%	30%	
B08 FR	20%	10	1	3	10%	30%	
B30 FR	20%	5	1	1	20%	20%	
B04 FR	10%	10	0	2	0%	20%	
B25 FR	10%	5	0	1	0%	20%	
B32 FR	10%	5	0	1	0%	20%	
B33 FR	10%	5	0	1	0%	20%	
B27 FR	0%	5	0	0	0%	0%	
B31 NF	40%	5	4	0	80%	0%	RR
B24 NF	10%	5	0	1	0%	20%	
Farm	% pos	comp	early finisher	finisher	early finisher	finisher	**Type**
B11 FF	47%	10	8	1	80%	10%	FT
B12 FF	45%	10	5	4	50%	40%	
B15 FF	40%	10	8	0	80%	0%	
B26 FF	40%	5	3	1	60%	20%	
B28 FF	40%	5	4	0	80%	0%	
B09 FF	33%	10	6	0	60%	0%	
B10 FF	32%	10	6	0	60%	0%	
B20 FF	30%	10	4	2	40%	20%	
B14 FF	25%	10	2	3	20%	30%	
B19 FF	25%	10	5	0	50%	0%	
B02 FF	20%	10	3	1	30%	10%	
B16 FF	20%	10	4	0	40%	0%	
B18 FF	20%	10	3	1	30%	10%	
B03 FF	10%	10	1	1	10%	10%	
B13 FF	10%	10	1	1	10%	10%	
B17 FF	10%	10	0	2	0%	20%	
B21 FF	5%	10	1	0	10%	0%	
B01 FF	0%	10	0	0	0%	0%	
B05 FF	0%	10	0	0	0%	0%	
B07 FF	0%	10	0	0	0%	0%	
B22 FF	0%	5	0	0	0%	0%	
B23 FF	0%	5	0	0	0%	0%	
B29 FF	0%	5	0	0	0%	0%	

comp = per compartment, FR = farrowing, NF = nursery, FF = finishing

Table S5.4: ESBL-E colonization in pigs (sorted by age and production step).

	Pig		Pig - ESBL		Pig - ESBL		
Farm	% pos	comp	young far./ newly we.	farrowing/ nursery	young far./ newly we.	farrowing/ nursery	**Type**
B35 FR	100%	5	3	4	60%	80%	FR
B30 FR	70%	5	3	4	60%	80%	
B33 FR	50%	5	4	1	80%	20%	
B27 FR	50%	5	1	4	20%	80%	
B34 FR	40%	5	2	2	40%	40%	
B25 FR	40%	5	2	2	40%	40%	
B06 FR	35%	10	7	0	70%	0%	
B04 FR	5%	10	1	0	10%	0%	
B08 FR	0%	10	0	0	0%	0%	
B32 FR	0%	5	0	0	0%	0%	
B31 NF	70%	5	3	4	60%	80%	RR
B24 NF	70%	5	4	3	80%	60%	
Farm	% pos	comp	early finisher	finisher	early finisher	finisher	**Type**
B02 FF	80%	10	10	6	100%	60%	FT
B20 FF	70%	10	8	6	80%	60%	
B19 FF	70%	10	10	4	100%	40%	
B01 FF	70%	10	4	10	40%	100%	
B22 FF	60%	5	5	1	100%	20%	
B10 FF	55%	10	10	1	100%	10%	
B18 FF	55%	10	6	5	60%	50%	
B28 FF	40%	5	4	0	80%	0%	
B09 FF	40%	10	8	0	80%	0%	
B12 FF	28%	10	2	3	20%	30%	
B29 FF	10%	5	1	0	20%	0%	
B13 FF	6%	10	1	0	10%	0%	
B15 FF	5%	10	1	0	10%	0%	
B14 FF	5%	10	1	0	10%	0%	
B17 FF	5%	10	0	1	0%	10%	
B07 FF	5%	10	0	1	0%	10%	
B11 FF	0%	10	0	0	0%	0%	
B26 FF	0%	5	0	0	0%	0%	
B16 FF	0%	10	0	0	0%	0%	
B03 FF	0%	10	0	0	0%	0%	
B21 FF	0%	10	0	0	0%	0%	
B05 FF	0%	10	0	0	0%	0%	
B23 FF	0%	5	0	0	0%	0%	

comp = per compartment, FR = farrowing, NF = nursery, FF = finishing

Table S5.5: MRSA isolates obtained from humans.

MRSA					
	Human samples		**Positive**		
Farms	negative	positive	Farmer	Staff	Family
B35 FR	0	2	0	2	0
B11 FF	0	2	1	0	1
B12 FF	0	2	1	0	1
B15 FF	1	1	1	0	0
B26 FF	1	1	1	0	0
B28 FF	2	2	0	1	1
B31 NF	0	2	1	0	1
B09 FF	2	2	1	0	1
B10 FF	1	1	1	0	0
B20 FF	3	1	1	0	0
B34 FR	0	1	0	1	0
B06 FR	1	2	1	1	0
B14 FF	2	3	1	1	1
B19 FF	2	1	0	0	1
B02 FF	1	0	0	0	0
B08 FR	4	0	0	0	0
B16 FF	1	2	0	2	0
B18 FF	2	0	0	0	0
B30 FR	2	3	1	0	2
B03 FF	1	0	0	0	0
B04 FR	1	2	1	0	1
B13 FF	1	1	1	0	0
B17 FF	2	0	0	0	0
B24 NF	1	0	0	0	0
B25 FR	1	1	1	0	0
B32 FR	0	3	1	1	1
B33 FR	0	1	0	1	0
B21 FF	1	2	1	1	0
B01 FF	1	0	0	0	0
B05 FF	1	1	1	0	0
B07 FF	3	0	0	0	0
B22 FF	0	2	1	0	1
B23 FF	3	0	0	0	0
B27 FR	3	0	0	0	0
B29 FF	0	1	1	0	0

FR = farrowing, NF = nursery, FF = finishing

Table S5.6: MRSA und ESBL-E colonization of pigs sampled on farms and abattoirs.

Farms							Abattoirs					
	ESBL-E pos			MRSA pos			ESBL-E			MRSA		
Farms	Negative	Positive	% Pos	% Pos	Negative	Postive	Time point 1	Time point 2	Time point 3	Time point 1	Time point 2	Time point 3
B02 FT	4	16	80%	20%	16	4	2	1	0	0	0	0
B19 FT	6	14	70%	25%	15	5	1	2	0	0	0	0
B18 FT	9	11	55%	20%	16	4	2	2	0	0	0	0
B15 FT	19	1	5%	40%	12	8	0	0	0	0	1	0
B14 FT	19	1	5%	25%	15	5	0	2	0	2	3	0
B16 FT	20	0	0%	20%	16	4	0	3	0	2	1	0
B13 FT	16	1	6%	10%	18	2	0	2	0	2	3	0
B17 FT	19	1	5%	10%	18	2	1	0	0	3	1	0
B29 FT	9	1	10%	0%	10	0	0	0	0	0	2	0
B03 FT	20	0	0%	10%	19	2	0	0	0	0	2	0
B07 FT	19	1	5%	0%	19	0	1	1	0	1	3	0
B21 FT	20	0	0%	5%	20	1	0	0	0	1	3	0
B23 FT	10	0	0%	0%	10	0	0	0	0	2	2	0

Table S5.7: MRSA und ESBL-E detection in farm air.

	Air samples			
	MRSA		ESBL-E	
Farm	negative	positive	negative	positive
B35 FR	0	2	2	0
B02 FF	0	2	2	0
B31 NF	0	2	2	0
B20 FF	0	3	1	1
B19 FF	0	2	0	1
B30 FR	0	2	2	0
B24 NF	1	1	2	0
B01 FF	1	1	1	1
B22 FF	0	3	2	0
B10 FF	0	2	1	1
B18 FF	0	2	2	0
B33 FR	0	2	1	1
B27 FR	0	2	2	0
B28 FF	1	1	2	0
B09 FF	0	2	2	0
B34 FR	0	1	2	0
B25 FR	0	2	2	0
B06 FR	0	2	1	1
B12 FF	1	1	2	0
B29 FF	0	2	2	0
B13 FF	1	1	2	0
B04 FR	0	2	2	0
B15 FF	0	2	2	0
B14 FF	0	3	2	0
B17 FF	0	2	2	0
B07 FF	0	2	2	0
B11 FF	1	1	2	0
B26 FF	1	1	2	0
B08 FR	0	2	1	0
B16 FF	0	1	2	0
B03 FF	1	1	2	0
B32 FR	0	2	2	0
B21 FF	0	2	2	0
B05 FF	2	0	1	0
B23 FF	0	1	2	0

FR = farrowing, NF = nursery, FF = finishing

Table S5.8: MRSA und ESBL-E detection in air on abattoirs.

Air samples			
Abattoir	MRSA / ESBL-E	t2	t3
Abattoir A	MRSA	+	-
		+	-
		+	-
		+	-
		-	-
		+	-
	ESBL-E	-	-
		-	-
		+	-
		+	-
		+	-
Abattoir B	MRSA	+	n.d.
		+	n.d.
		+	n.d.
		+	n.d.
		+	n.d.
		+	n.d.
		+	n.d.
		+	n.d.
	ESBL-E	+	n.d.
		-	n.d.
		+	n.d.
		+	n.d.
		-	n.d.
		-	n.d.
		-	n.d.

t = time point, n.d. = not determined

Table S5.9: *MRSA und ESBL-E detection in air on abattoirs.*

	Pig							Human					Air								
farms / ***spa* types**	t011	t034	t108	t1255	t1451	t1456	t2011	t011	t034	t1255	t2011	t2330	t011	t034	t108	t1255	t1451	t2011	t2123	t898	SUM
B14	2	1						2		1			2								8
B11	1				2			2					1				1				7
B12	3							2					2								7
B35	2							2					2								6
B32	1							3					2								6
B30	1			1				1		2						1					6
B06	1						1	2					1					1			6
B16			2					1	1						2						6
B13	2							1					2								5
B10	1								1				1	1	1						5
B26	2							1					1	1							5
B34	2							1					2								5
B15		1						1						3							5
B28	1							1	1				2								5
B09		2						1	1					1							5
B20	2											1	1		1						5
B02	2												1		1						4
B19	1		1								1		1								4
B31		1						1	1				1								4
B24	1												2	1							4
B25		1						1					1	1							4
B03		2												2							4
B21	1							2					1								4
B04		1						1	1					1							4
B22								2					1	1							4
B08	2												1								3
B33	1							1					1								3
B17						1														2	3
B18	1																		1		2
B01													1		1						2
B29								1					1								2
B23													1	1							2
B05								1					1								2
B07													1								1
SUM	30	9	3	1	2	1	1	31	6	3	1	1	34	13	6	1	1	1	1	2	
in %	64%	19%	6%	2%	4%	2%	2%	74%	14%	7%	2%	2%	58%	22%	10%	2%	2%	2%	2%	3%	

6 Visualization of key performance indicators during assessment of suppliers in the meat industry

This article has been published in German:

LENA MEINDERS[1], SOPHIA SCHULZE-GEISTHÖVEL[1], HANS-JÖRG EYNCK[2], FRIEDHELM JAEGER[3], BRIGITTE PETERSEN[1] (2015)

Visualisierung von Key Performance Indicators bei der Lieferantenbewertung in der Fleischwirtschaft

In: Bericht zur GQW-Jahrestagung 2015 Band 17/2015 Shaker Verlag S. 125-144.
ISBN: 978-3-8440-3351-9

[1] Institut für Tierwissenschaften, Rheinische Friedrich-Wilhelms-Universität Bonn
[2] Tönnies Lebensmittel GmbH & Co. KG

[3] Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen, Schwannstraße 3, D-40476 Düsseldorf

*Corresponding author: Sophia V. Schulze-Geisthövel.
Email: s.schulze-geisthoevel@uni-bonn.de

6.1 Abstract

Animal welfare has become socio-politically increasingly meaningful. Consumers of meat products are interested in how the animals are kept. System reorganization in animal husbandry and animal health management has become a criterion for quality in the value chain. In the case of pork production, this presupposes that all parties involved—from animal husbandry to slaughter to marketing—are ready to make system alterations. Rapid system changes depend on the ability of the involved enterprises to learn from errors during the conversion process.

In the example on mitigating the system for boar fattening, the AMOR approach (**A**lliances for the **M**utual **O**rganization of **R**isk oriented inspection strategies) is described, in which criteria are defined for representing learning effects.

A goal of this study was to make the learning effects, during alteration of the system, measurable and descriptive with concrete criteria. With the help of the Six Sigma concept (DMAIC cycle), an action concept was developed for more rapid conversion—by outside improvement processes—in the management of animal-holding and animal-slaughtering enterprises. For this purpose new key performance indicators were defined.

There were 294 boar-supplying enterprises and one abattoir that participated in this study. Results of the evaluation by the existing method of measuring smell deviation of carcass halves (human-nose

method) formed the basis for the development of a retrospective operation to reclassify the suppliers into five risk categories.

By way of onsite audits at nine selected agricultural operations, a production-accompanying procedure was developed. Two risk indices related to the management of pig fattening and the organization of transport and rest periods before slaughter were computed from a catalog comprising 40 criteria.

The Six Sigma concept is suitable for combining both procedures into a concrete procedural model, which derives benefit from the effects learnt during reorganization of the system for fattening boars within the customer-supplier relation.

6.2 Introduction

In Germany—due to the amendment of the Animal Welfare Act—starting in 2019 piglets may no longer be castrated without anesthetization. A possible alternative in which surgical castration can be perfectly eliminated is boar fattening. However, this poses new challenges to both the pig-holding and slaughtering enterprises. One challenge includes the risk of smell deviations in the meat (caused by androstenone and skatole), which could result in difficulties with marketing the boar meat (Heid 2011).

If such complex processes are changed, system innovations are necessary. These cover far more than only technological changes. They are realized by changes in infrastructures, institutions, and benefit behavior. Organizational changes, which contribute to a process improvement, are of particular interest (Schneidewind & Scheck 2013).

Presently, preliminary information concerning the animal's origin for appropriate risk-oriented sorting at the slaughterhouse has not yet been used. So far the sorting of carcass halves for marketing in the fresh meat segment, on the one hand, and the processing to boiled ham, on the other hand, takes place by means of a very complex and expensive full examination via the human nose method (Mathur et al. 2012) for each boar that is delivered to the slaughterhouse. The risk of smell deviations can be better assessed by sequential risk-oriented control strategies, if further preinformation about the holding of origin, transport to the slaughterhouse, and the latency period before slaughtering would be available. From the literature and numerous pilot projects, it is already well known which factors can increase the risk of smell deviations (Windig et al. 2014; Zamaratskaia & Squires 2008; Looft et al. 2014; Aluwé et al. 2011). However, the number and combination of these factors for each establishment of origin and each constellation of transport and rest period are different. Therefore, in this study the question was explored as to what extent data from previous slaughters by boar-supplying operations make a statement on predictive values for the number of expected smell deviations. Furthermore, it should be examined in which way and with which methodological approach the supplier evaluation and the promotion of counselling measures would let themselves improve. Concerning this, key performance indicators (KPIs) were determined and visualized that reflect the common achievement of slaughterhouses and their suppliers in the context of the system conversion. The advantage of such characteristic numbers is that they can simplify comparatively complex, economical facts and be expressed as a single number whereby comparisons are allowed (Fitz Gibbon 1990; Parmenter 2010; Meensel et al. 2010; Düsseldorf 2013).

6.3 State of knowledge

6.3.1 System conversion into boar fattening

In the past years a set of scientifically accompanied projects has been accomplished—each with pro and cons—and the opportunities and risks of boar fattening were analyzed. A good preparation for the shift from fattening male or female pigs to the fattening of boars is necessary for both animal keepers and slaughterhouses. The prevalence for boar odor can be affected by feed, hygiene, slaughter weight, and genetics, as well as by many other factors individual for each operation (Looft et al. 2014; Aluwé et al. 2011; Tholen 2010; Susenbeth 2012; Weis 2004; Quiniou et al. 2010; Schulze Langenhorst et al. 2010; Krieter 2010). Also, the way the animals are transported to the slaughterhouse and the organization and handling in the dry sow house can be crucial for changing the smell in carcass halves. Stress leads to the appearance of boar odor (Sherritt 1972).

The conversion to boar fattening is a very current sector. It has necessitated an intensive mutual inspection between slaughterhouse and its suppliers. The realization of the AMOR approach was described (O‘Hagan et al. 2013).

Team-oriented methods of quality planning—which was represented for this sector of the economy by Schmitz (2006), Ellebrecht (2012) and Brinkmann and Petersen (2011)—and testing for different quality goals play an important role in this context.

Key performance indicators—which state characteristic numbers over the procurement efficiency or false ratio of deliveries—facilitate communication between customers and suppliers and, thus, between the different stages of the added value chain of meat (Klauke & Brinkmann 2009).

6.3.2 Methods to minimize errors in the context of process improvement

A team-oriented method for error minimization in the context of process improvement is the Six Sigma concept (Lieber & Moormann 2004). Six Sigma was used for the first time at the end of the 1980s by Motorola. Since then it has found many cross industry applications. The Six Sigma approach is a method in the quality management with the goal of achieving as error free a process as possible. Cost of quality can be reduced by the analysis of the actual process by the Six Sigma method.

For the introduction of Six Sigma, a five-stage flow diagram in practice has proven its worth. This is the DMAIC approach (define, measure, analyze, improve, control), which as a cyclic model that serves the purpose of reducing systematic errors (Kaminske & Brauer 2008). In this model under each individual criterion the methods and tools of the quality management, represented in Table 6.1, are systematically used.

Table 6.1: Goals, tasks, tools, and results in different phases of the DMAIC cycle; modified according to Lang & Petersen (2012)

Phase	Aim	Main tasks	Tools	Results
Define	Define the project	-Description of the initial situation Getting an overview -Defining the project	Project plan	Overview of the overall situation Project assignment
Measure	Determine the initial situation	- Implementation of existing data -Collection and evaluation of existing data	Pareto analysis	A facts-based understanding for improving the situation
Analyze	Define relevant causes	-Identifying potential main influencing factors	Cause-and-effect analysis	Proven connections
Improve	Develop and test solutions	-Testing solutions -Valuing solutions -Planning the implementation	FMEA	Release for implementation
Control	Implement optimal solutions	-Fixing the solutions -Safeguarding the improvements -Concluding the project	Trainings Techniques for prognosis Valuation techniques Visualization trends Control chart Matrix diagram	Improved conditions Completion of the project

Klauke and Brinkmann (2009) established that the statistical quality goal of Six Sigma is also applicable in food production. These authors tested the preventive tools by an example from the added value chain of pork. KPI and quality criteria being comparable over each step were examined. Thus, quality and the degree of cross-company cooperation among fattening, slaughter, and processing could be pointed out (Klauke & Brinkmann 2009). In this context the use of the AMOR approach is meaningful.

A substantial characteristic of the AMOR approach is the formation of alliances among different participants of the chain for the common execution of risk-oriented test strategies. Two view levels characterize the AMOR approach: cooperation to the mutual benefit and risk-oriented organization of verifications (Petersen et al. 2014). Outside information and communication systems conduce to this purpose (O'Hagan et al. 2013). Collaboratively organized added value chains exchange information along the chain. In this process communication on quality takes place between the companies (business-to-business, b-to-b). In Figure6. 1 the advantages of the AMOR approach are presented.

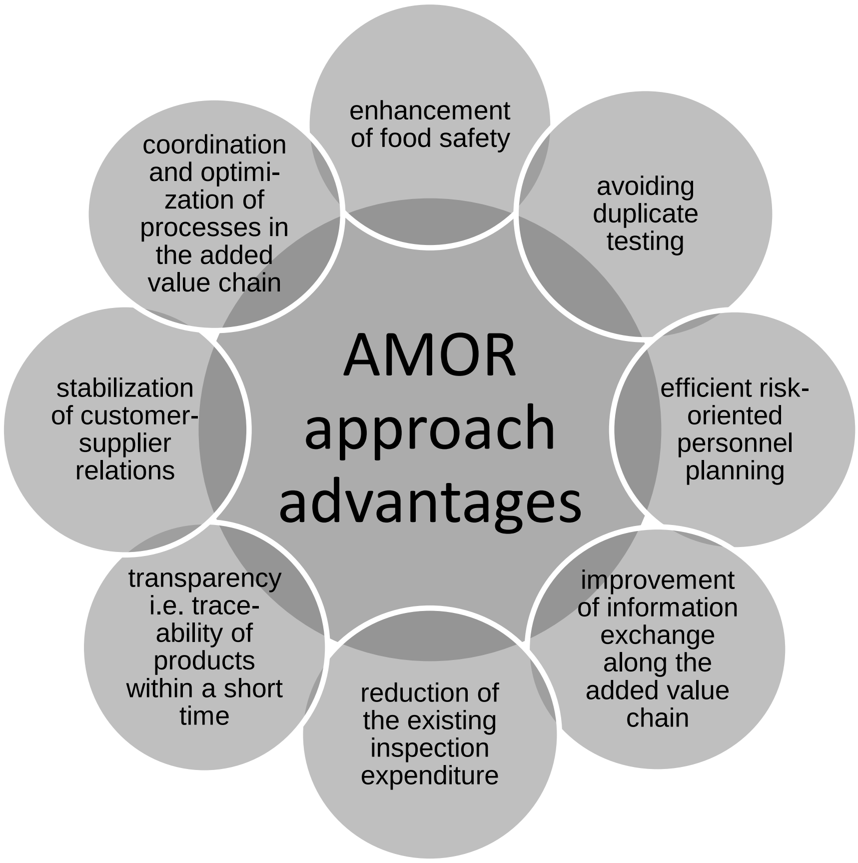


Figure 6.1: Advantages of the AMOR approach; modified according to Lang & Petersen (2012) and Petersen et al. (2014)

The value of information exchange has resulted from the growing requirements in security and quality of food. In addition, demands for enhanced transparency in the production chain have played a large role in increasing the meaning of information exchange. The increased transparency in the added value chains in the agrarian economy and in food production is supported by various initiatives:

- Legislation for the improvement of transparency in the added value chains in agrarian and nutrition economy
- Certification systems for differentiation of the product offer and information about quality characteristics
- IT systems for improved access to information

The latter is particularly important in the communication between agricultural enterprises and slaughterhouses (Petersen et al. 2014). In addition, software such as “Schlachtdaten online,” “Chainfood,” “FarmingNet,” and “Farmer’s Friend” allow information transmission from slaughtering to the agricultural delivery operation. Thus, it is possible for these participants to review on a regular basis among themselves fixed agreements and specifications concerning the deliveries and to recognize possible flaws (Petersen et al. 2000). Several authors have referred to the improvement process, which is caused by dispersion of information and the mutual exchange of information (O‘Hagan et al. 2013; Brinkmann &

Petersen 2011; Schulze Althoff 2006). Nevertheless, the disclosure of information and the information exchange are not yet sufficiently developed and need to be strengthened.

6.4 Material und Methods

6.4.1 Selection and categorization of the pilot operations

In order to first find suitable operations to join the project, the slaughterhouses made anonymous data available of 294 delivery enterprises for the period January 2012 to June 2014. This data contained an anonymous code for feedback to the respective operation, distance to the slaughterhouse, number of delivered boars in the entire period, the total number of smell-deviating animals, the dates of slaughter with the pertinent numbers of supplied boars, and, again, pertinent numbers of smell-deviating animals per slaughter date.

To be able to evaluate this data, the proportional number of smell-deviating boars and the percentage of the total smell-deviating animals were determined per slaughter date since the beginning of boar delivery.

Thereto, the following formulas were used:

$$\boldsymbol{proportional\ number\ of\ smell - deviating\ boars\ per\ slaughter\ date} = \frac{smell - remarkably\ boars}{slaughtered\ boars\ per\ slaughter\ date}$$

$$\boldsymbol{smell\ off - types\ \ in\ the\ total\ time\ area} = \frac{smell - remarkably\ boars}{slaughtered\ boars\ in\ the\ total\ time\ area}$$

Using Excel, diagrams have been generated for each fattening operation with the aim of assigning the operations into several categories (Figure 6.2). Category 1 contains operations that were continuously inconspicuous regarding smell deviations per slaughter date.

The portion of boars that show smell deviations may not exceed 3.7%. The second category operations continuously improve over the course of the slaughter dates. The third category describes enterprises that steady worsen over the course of time. Contrary to the first category, the operations subordinated in category 4 exhibit constantly high smell deviations. The total deviation here is greater than 4.5%. Additionally, the operations must show continuity in high smell deviations. In category 5, no trend is clearly identified. The enterprises perform, again and again, differently—well and/or badly.

Categories 3, 4, and 5 do not dominate the process, since the proportion of odor drift is above the limit value of 3.7%.

From each category in each case two operations were selected and contacted. In category 4 (continuously conspicuous) only one enterprise could be selected for the project, since the others, which also belonged to this category, had already adjusted to the boar fattening. Thus, altogether, nine fatteners remained for the development of a production-accompanying procedure for determining key performance as well as key risk indicators.

To better compare the research results, the waiting time and method of stunning were standardized. This was, for the purposes of the ministry, to better the time before and during slaughter. It was ensured that the pilot farms selected for this study had no extremes regarding travel time of the pig truck. All boar groups remained in the waiting pen for 1.5 hours and were anesthetized with CO_2. This stunning method was chosen because it is used in most abattoirs and the results are, therefore, transferable.

Subsequent to the execution of the experimental study, a similar categorization for the period January 2012 to June 2014 was made with a continuation of the categorization of the 294 delivery enterprises. This is visually presented in Figure 6.2 for the nine pilot operations over the period January 1, 2012, to November 19, 2014.

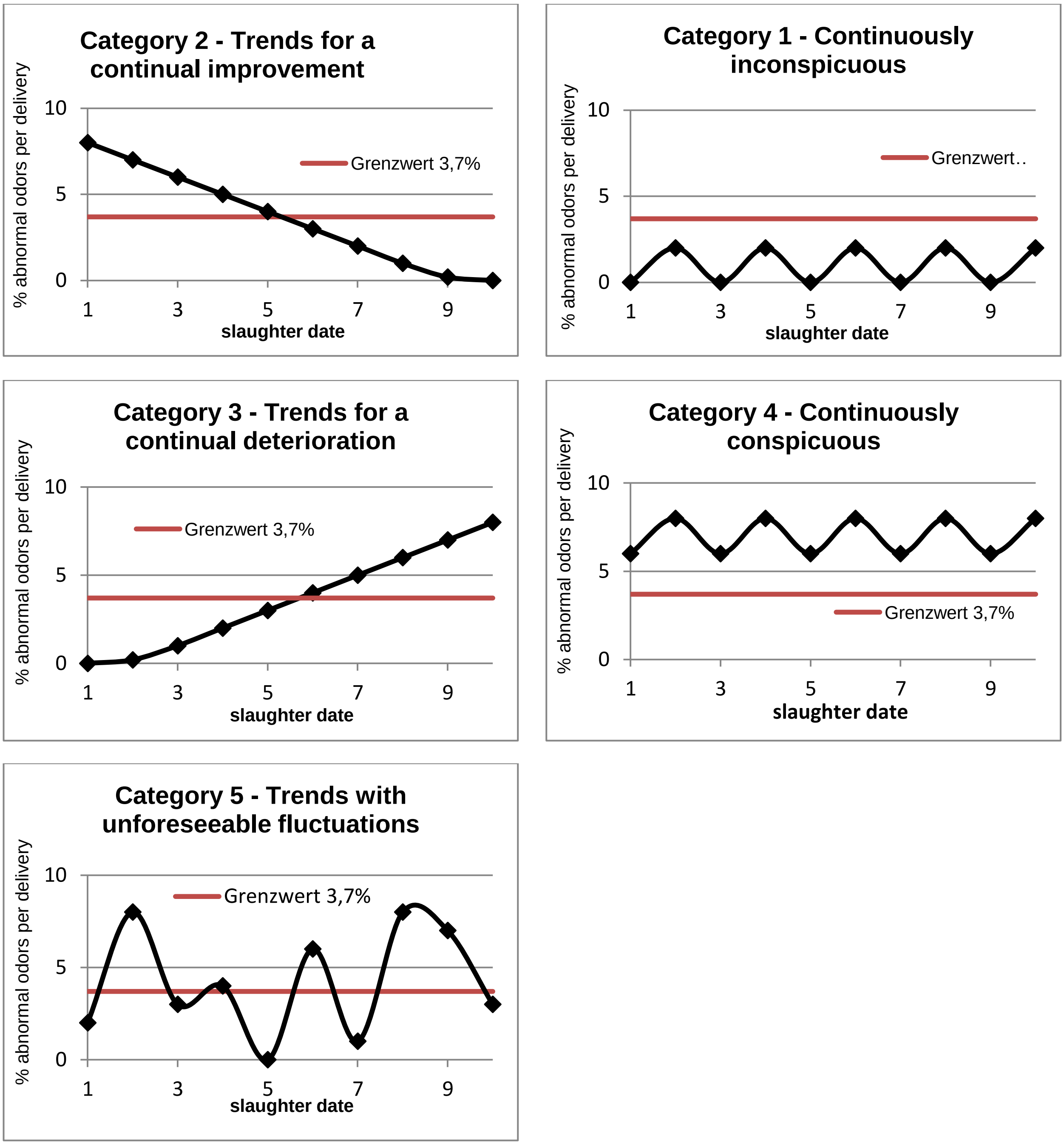


Figure 6.2: Idealized trend curves for categorizing the course of the percentage of carcasses with abnormal odors per delivery date and farm

6.4.2 Audit questionnaires and audit checklists

During the farm visits a systematic collection of company-specific data by questionnaire took place. This data was collected for determining the risk indices. Five areas have been considered:

- Key performance indicators
- Stable management
- Feeding
- Cleaning and disinfection
- Hygiene measures

The number of questions asked were 37. Some of the questions were open in order to gather key production figures of the pilot farms, while others were closed questions. For the acquisition of data on animal behavior and animal health during transport to the slaughterhouse and in the dry sow house prior to the slaughter period, an audit checklist was used. In the checklist the following criteria were recorded:

- Transport duration
- Observation of animals
- Behavior of the animals in the dry sow house

The observation form was filled out by a third person. This was the same for each audit.

6.4.3 Sequence of production-related audits and monitoring of health data

Between August and October 2014 blood samples were collected for serological examination. Samples were taken during slaughter from the indicator-animals of the nine selected farms.

The observation area and schedule for production-attendant data collection was subdivided at the slaughterhouse, as shown in Table 6.2, into six phases. First, the transporter was ordered to the appropriate ramp where the driver participated in a brief survey about the trip. He was asked (1) where he had picked up the pigs, (2) how long the trip was, and (3) whether he had been stuck in traffic. Subsequently the pigs were unloaded routinely from the driver by the staff of the slaughterhouse. In the dry sow house intensive monitoring of the boars took place. Thereby, checklists were completed that created a pictorial record. After the animals had the opportunity to rest in the dry sow house for 1.5 hours, they were slaughtered.

The slaughter procedure commenced with the pigs from the pilot farms being marked. The AUTO-FOM unit was then used. The AUTO-FOM unit (Automatic Fat-O-Meater) is a classification apparatus that performs a fully automated measurement of the lean meat, taking into account the portion of information (value and weight of, for example, shoulder and ham). The blood samples were taken after slaughter.

Table 6.2: Phases of production-accompanying audit and monitoring proceedings

Phases at the slaughterhouse	Activities	Determined raw data
1	Logistics management Pig transporter	
2	Questioning of the driver	Transport time
3	Delivering the pigs	Parameters for index before slaughter
4	Observing the boars in the dry sow house	Parameters for index before slaughter
5	Marking the pigs of the pilot operation before Auto-FOM	Company and slaughter number
6	Blood sampling after slaughter	Blood tests for determining the illness index

Within the scope of this project, ten blood tests per observation day were taken. The number of animals supplied per enterprise varied. Altogether, 610 pigs were observed and 90 blood tests were sent to the laboratory.

In the laboratory the blood tests were examined serologically for five agents of infection:

- Mycoplasma hyopneumoniae (M. hyo)
- Actinobacillus pleuropneumoniae serotype 2 (APP2)
- Swine influenza (SIV)
- Porcine reproductive and respiratory syndrome virus (PRRSV)
- Porcine circovirus type 2 (PCV2)

The monitoring results served to estimate the health status of the origin enterprise. Further parameters that were gathered at the slaughterhouse by investigators belonged to the following evaluations:

- Medical evidence of organs
- Inspection of carcasses by Auto-FOM
- *Salmonella* monitoring
- Tetracycline monitoring
- Odor deviation

The data above results from routinely collected data for an agricultural delivering operation these data are collected in regular intervals to determine proceeds for the delivery.

6.4.4 Evaluation of the measurement and survey data

For both the management of the origin enterprise and the processes during transport and stay in the dry sow house, a risk index related to the supplier was computed in each case. Six parameter groups formed the basis on which the indices were calculated. Each parameter was assigned and/or classified to a three-point scale according to its markedness (Table 6.3).

Table 6.3: Exemplary scaling system

Class	Definition
1	very well
2	satisfactory
3	inadequate

The 31 parameters were again subdivided into six groups, from which the calculation of the group index followed. The index "management of origin enterprises" was recomposed from the partial indices listed in Table 6.4.

Table 6.4: Definition of the groups of parameters for index "management of origin enterprises"

Designation of the group indices	Variable
Index for working with key performance indicators	h1
Index for estimating possible risks	h2
Index for self-assessment	h3
Index for outward distinctive features	h4
Disease index	h5
Index of *Salmonella* status	h6

The overall index was calculated by the sum of the group indices divided by the number of groups:

$$\frac{\sum \boldsymbol{h1-j}}{\boldsymbol{N}}$$

$h_{1\text{-}j}$ = partial indices

N= number of groups

For calculating the dry sow house index, the parameters specified in Table 6.5 were used.

Table 6.5: Organization of the parameters for the dry sow house index

Parameter	Variable	Category		Definition
Race concerning unrest in the dry sow house	y1	1		Duroc
		3		Piétrain
Unrest in the dry sow house	y2	1		Calm
		2		Slight unrest
		3		Great disquiet
Composition within the dry sow house	y3	1		Boars and sows together
		3		Sexes are separated
Vocalizations	y4	1		Little
		2		Medium
		3		Much
Riding up	y5	1		< 15 times
		2		15 to 49 times
		3		> 50 times
Ranking fights	y6	1		< 5 times
		2		6 to 9 times
		3		> 10 times
Minutes until first animal laid down	y7	1		< 15 min
		2		16 to 35 min
		3		> 35 min
Minutes until all animals laid down	y8	1		< 30 min
		2		31 to 60 min
		3		60 min to not at all
Recent skin injuries	y9	1		Not recognized
		2		Recognized
		3		Strongly recognized

$$\frac{\sum \boldsymbol{y1-j}}{\boldsymbol{Ny}}$$

$y_{1\text{-}j}$ = partial indices

Ny= number of groups

A further evaluation was conducted with photographs that were provided by the slaughter operation. The photographs were taken after the pigs had already been cleaned and scorched. The photographs of the individual enterprises were divided into 3 categories (see Figures 6.3–6.5).

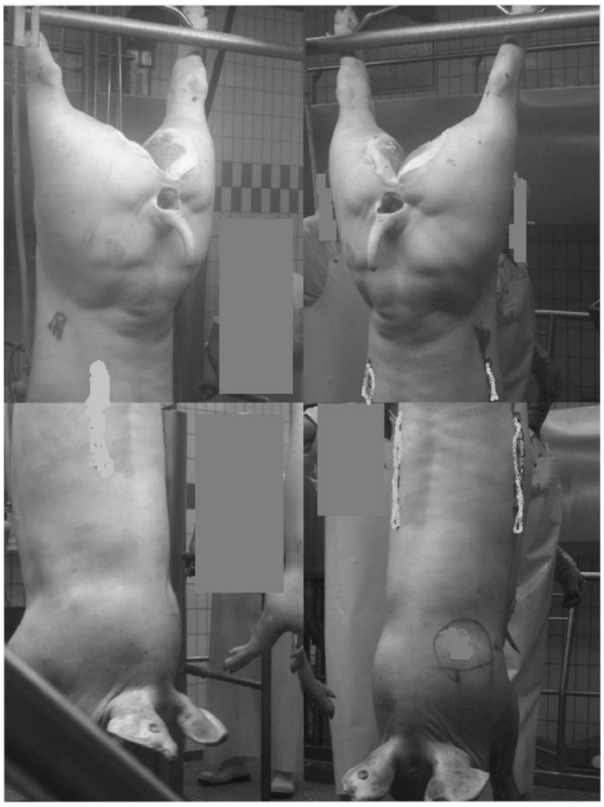


Figure 6.3: Carcass category of good

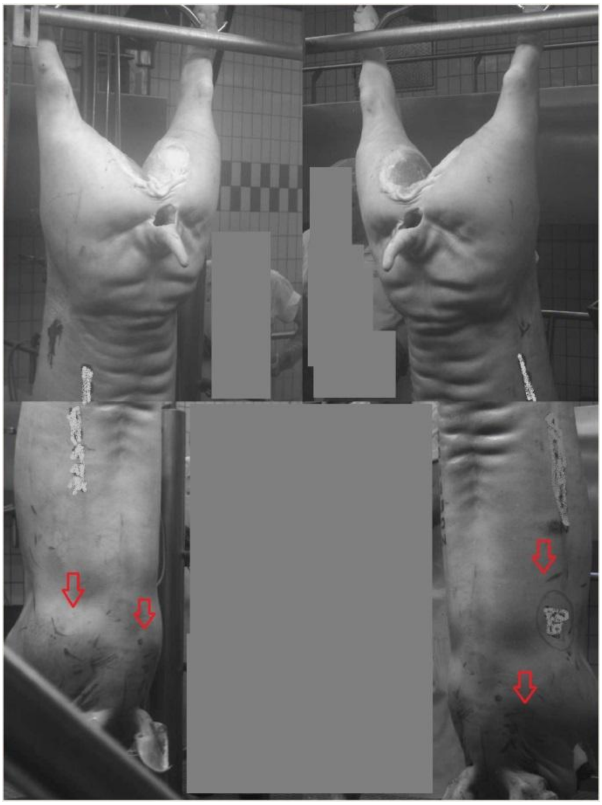


Figure 6.4: Carcass category of medium

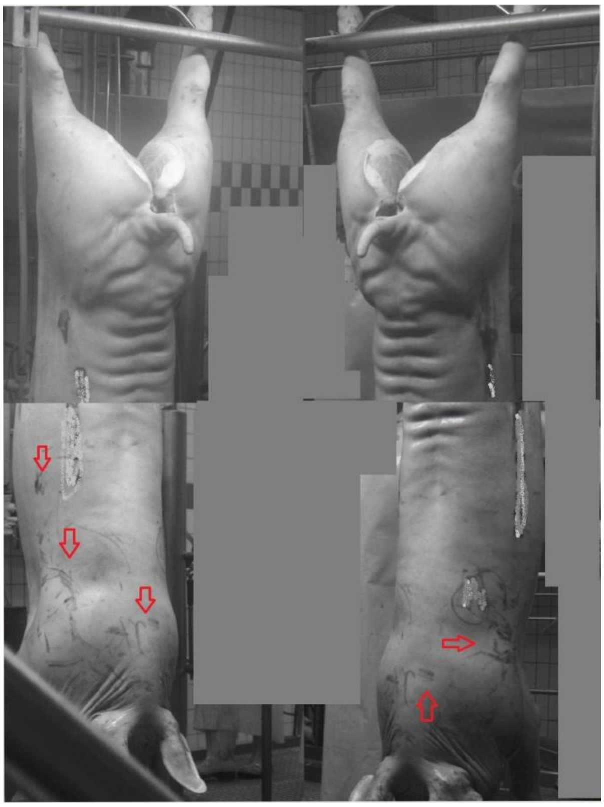


Figure 6.5: Carcass category of bad

A separate evaluation of the blood results took place in accordance with the serology indexing of Düsseldorf (2013). This serology index (SI) is described by the following formula:

$$\frac{P(PRRSV) + P(PCV2) + P(M.hyo) + P(SIV) + P(APP2)}{500}$$

Here, P presents the percentage of seropositive blood tests per pathogen. The sum of the P values is divided by 500, where 500 is the maximum that can be achieved if all samples of the five analyzed pathogenic agents were positive. Thereby, the SI value moves between zero and one. An SI of one indicates an increased disease pressure and an SI of zero the absence of an enzootic risk.

After the execution of the production-accompanying audits of operations, the slaughter enterprise again provided anonymous data for the period of July 2014 to November 2014. This was done to continue the organization of the enterprises into the five ideal-typical trend curves to classify the proportion of carcasses with odor deviations per delivery and operation. Withal it could be determined how far a predictive value of the operations can be made. Similar to the procedure for the selection and categorization of the pilot operations, all enterprises were categorized.

On the basis of the provided data and with the help of the statistical program "R version 302," the correlation between husbandry-conditioned medical evidence of organs:

• tail tip necrosis • front limb inflammation • back limb inflammation • front limb joint inflammation • back limb joint inflammation	**husbandry-conditioned medical evidence of organs**

and odor deviation, and the correlation between infectious disease:

• pleurisy < 10% • pleurisy 10–30% • pleurisy > 30% • pulmonary changes < 10% • pulmonary changes 10–30% • pulmonary changes > 30%	**infectious diseases**

and odor deviation were researched. The individual parameters were unweighted. In addition, an odds ratio was first determined in order to check the extent to which the variable influences smell deviations of meat. The step-by-step logistic regression was used to statistically evaluate the data.

For visualization of the index values, the control chart principle was selected. It concerns a graphical presentation of risk characteristic numbers with an indicated setpoint value, a warning value, and an intervention limit. The desired value represents the process optimum. The warning value marks an irregularity in the process; however, the process was still within the tolerance. Crossing the intervention limit signals substantial errors and implies a need for action.

Related to the one-sided control chart used here for the determined risk indices, the following borders were specified:

- setpoint value = 1
- warning value = 1,5
- intervention limit = 2

6.5 Results

6.5.1 Assessment of suppliers on the basis of retrospectively determined risk categories

As indicated by the frequency distribution in Figure 6.6, only 14% of the 294 operations were classified into the category "continuously inconspicuous" (category 1). Among the boar fatteners who could improve continuously regarding a reduction in the portion of animals with smell deviations, 18% belong to category 2. Regarding the odor characteristic, only 5% of the enterprises worsened continuously (category 3) and only 4% were continuously remarkable regarding odor deviations (category 4).

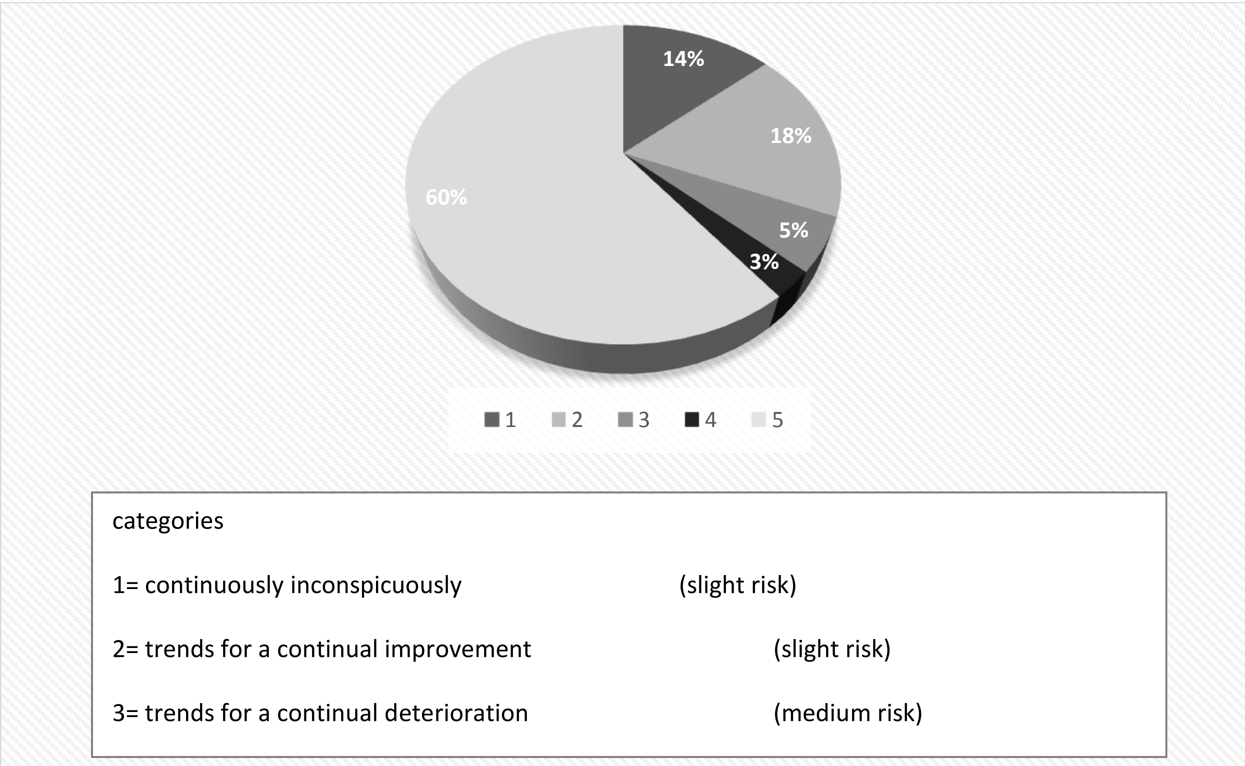


Figure 6.6: Proportional part of the 294 supplier operations in the categories 1–5

It is reckoned that for animals from operations in categories 1 and 2, the risk for the occurrence of smell deviations in the future is small. This means for the slaughterhouse that it can predict in all probability that the enterprises will deliver slightly odor-remarkable boars. Thus, internal processes and the inspection frequency for the assortment can be coordinated with it.

Enterprises from categories 3 and 4 have a high probability of delivering smell-remarkable boars. Due to the fact that this presents a clear trend for the slaughterhouse, the risk and/or uncertainty is classified as medium. Here the slaughterhouse can also predict that more boars with smell deviations will be delivered and so the processes can be adjusted accordingly.

From figure 6.6 it is evident that most boar-keeping operations were assigned to category 5. These do not show a recognizable trend for the number of odor deviations per slaughter. For these enterprises the risk for the slaughterhouse is high, since there is no predictive value concerning the smell-deviating enterprises.

6.5.2 Assessment of suppliers on the basis production-accompanying determined risk indices

The risk indices that serve for the calculation of an overall index of "management origin enterprise" are shown in Tables 6.6 to 6.11. Table 6.6 shows the results from both retrospective data and production-accompanying audits concerning working with key performance indicators.

Table 6.6: Auditing index for working with KPIs

	Category 1		**Category 2**		**Category 3**		**Category 4**	**Category 5**	
Operation identification	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Daily gains in fattening	3	1	1	1	1	3	1	1	1
Fattening duration (boar)	1	1	1	1	1	3	1	1	1
Age of in-housing	1	1	1	3	3	3	1	3	1
Age of housing out	1	1	1	3	3	3	1	1	1
Weight by in-housing	1	1	1	1	1	1	1	1	1
Weight by housing out	1	1	1	1	1	1	1	1	1
Feed requirement	3	3	3	3	3	3	1	1	1
Total animal losses	1	1	1	1	1	1	1	1	1
Index for working with KPIs	***1.5***	***1.25***	***1.25***	***1.75***	***1.75***	***2.25***	***1***	***1.25***	***1***

Working with key performance indicators provide information about how far farmers are informed about their operation and whether they use this information for a constant learning process. The pertinent parameters such as the age and weight of in-housing are important keys performance indicators for the risk of boar odor. A longer fattening (e.g. under diseases) carries the hazard of higher smell deviations of carcasses. It must be clearly recognized that the highest indices were calculated for category 3 (with trends for continuous degradation). Only operation G (category 4) and operation I (category 5) achieved the optimal index of 1. These two enterprises were well informed about the operational management and work with key performance indicators.

The results from the audit "estimating possible risks" are presented in Table 6.7.

Table 6.7: Auditing index for estimating possible risks

	Category 1		Category 2		Category 3		Category 4	Category 5	
Operation identification	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Variations in temperature	1	1	1	1	1	1	1	1	1
Group size	2	1	2	1	1	1,5	2	2	2
Ventilation cleaning	1	2	2	2	2	2	1	1	1
Cleaning soaks	3	3	2	3	1	2	1	3	3
Feed cleaning	1	1	2	3	1	1	1	3	1
Stable cleaning	1	1	1	1	1	1	1	1	1
Stable disinfection	1	1	1	1	1	1	1	1	1
Conversion of hygiene measures	2	3	2	2	3	3	2	2	2
Index for estimating possible risks	***1.5***	***1.63***	***1.63***	***1.75***	***1.38***	***1.56***	***1.25***	***1.75***	***1.5***

The index for estimating possible risks encloses group management, processes of cleaning, and hygiene measures. They affect the health of the animals. Smaller animal groups can be better observed than large groups. Injured or suffering animals can be identified faster. The cleaning of stable equipment such as feeding facilities or ventilation is important in order to keep the microorganism density as small as possible and, therewith, prevent disease. From Table 6.7 it becomes clear that no operation is outstandingly good and/or bad concerning the index. The values rank between 1.25 and 1.75.

Table 6.8 covers the self-assessment of the agricultural delivery operations related to categorization. For this purpose the interviewees had to estimate themselves.

Table 6.8: Auditing index for self-assessment

	Category 1		Category 2		Category 3		Category 4	Category 5	
Operation	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Index for self-assessment	**2**	**1**	**3**	**3**	**3**	**3**	**3**	**1**	**2**

The self-assessment index classifies the self-assessment of farmers into a category. The correct classification was evaluated as *good*. It signals the farmer has good information about their enterprise concerning smell-deviating animals and shows the intensive dealing with data, which is sent by the slaughter operation. This can, therefore, be graded as positive. A *too bad* classification is more badly evaluated. Information about a farmer's own enterprise does not seem to be fully matured. Nevertheless, this is to be evaluated more positively than a too positive classification of an enterprise into a category. Operations of the first and last categories (operations A and B, H and I) achieved a better index than categories 2, 3, and 4.

Table 6.9 shows the index for "outward distinctive features," which were observed at the slaughterhouse during the 1.5 hour latency.

Table 6.9: Observations at the slaughterhouse for the outward distinctive features index

	Category 1		**Category 2**		**Category 3**		**Category 4**	**Category 5**	
Operation	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Red-rimmed eyes	1	1	1	1	1	1	1	1	2
Smeared eyes or nose	1	1	2	2	1	1	2	1	2
Ancient skin injuries	1	1	1	1	2	2	2	1	1
Dirt	1	2	1	1	1	1	1	2	2
Tail-tip injury	1	2	1	1	1	2	1	2	2
Wounds at the ears	1	1	1	1	1	1	1	1	1
Foundation problems	1	1	2	1	2	1	1	1	1,5
Index for outward distinctive features	**1.00**	**1.29**	**1.29**	**1.14**	**1.29**	**1.29**	**1.29**	**1.29**	**1.64**

With the index for outward distinctive features such as the amount of dirt, ancient skin injuries, tail wounds, or foundation problems, conclusions can be drawn about the husbandry of the animals. These features can be caused by wrong management. Here intensive animal observation and intervening in problematic cases can result in improvement. The operations exhibit among themselves only a few differences concerning the outward shape during the animal observation at the slaughterhouse. Enterprise A evinces the best index. The animal observations were subjective; however, they were always performed by the same person so that comparability exists.

In Table 6.10 the measurements of the blood results for the illness index are shown.

Table 6.10: Results of the blood tests for the illness index

	Category 1		Category 2		Category 3		Category 4	Category 5	
Operation	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
PRRSV	3	1	1	3	3	3	3	1	1
APP	1	1	1	1	1	1	1	1	1
Swine influenza	1	1	1	1	3	3	1	1	1
PCV2	1	1	1	1	1	3	1	1	1
M. hyopneumoniae	1	1	1	3	1	1	1	1	1
Content of haptoglobin	3	1	3	3	3	3	1	1	1
Illness index	**1.67**	**1.00**	**1.33**	**2.00**	**2.00**	**2.33**	**1.33**	**1.00**	**1.00**

The illness index is an important key performance indicator. Only healthy animals can obtain high achievements. Diseases within the population reduce the potential efficiency and cause additional costs both on the level of the animal keepers and for the slaughter enterprise. While category 5 and enterprise B from category 1 exhibit an optimal index, the index values related to the diseases are different, as is the content of haptoglobin in the remaining categories. It can be clearly recognized that PRRSV is far spreading. This illness obviously weakens the disposition and performance of the animals. In 56% of the operations, the content of haptoglobin was increased and also refers to an inflammatory illness.

In Table 6.11 the *Salmonella* index for the nine delivery operations is shown. The slaughterhouse takes over *Salmonella* monitoring and passes the information back to the organization and the farmers. The status classification takes place into three categories:

- Category I: up to 20% positive evidence of *Salmonella* antibodies
- Category II: more than 20% up to 40% positive evidence
- Category III: more than 40% positive evidence

Table 6.11: Auditing index of Salmonella status

	Category 1		Category 2		Category 3		Category 4	Category 5	
Operation	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Index of Salmonella status	1	1	1	1	2	1	2	1	2

In this study there were only enterprises with a *Salmonella* status of 1 and 2. The *Salmonella* status index is important for disclosing a functioning operating management. *Salmonella* can be transferred through contaminated food to humans. Therefore, it is very important to control the *Salmonella* status and improve it when necessary. By feedback of the information from the slaughterhouse, this is possible for the agricultural enterprise.

These indices can be combined, as shown in Figure 6.7, into a total risk for the management origin enterprise risk.

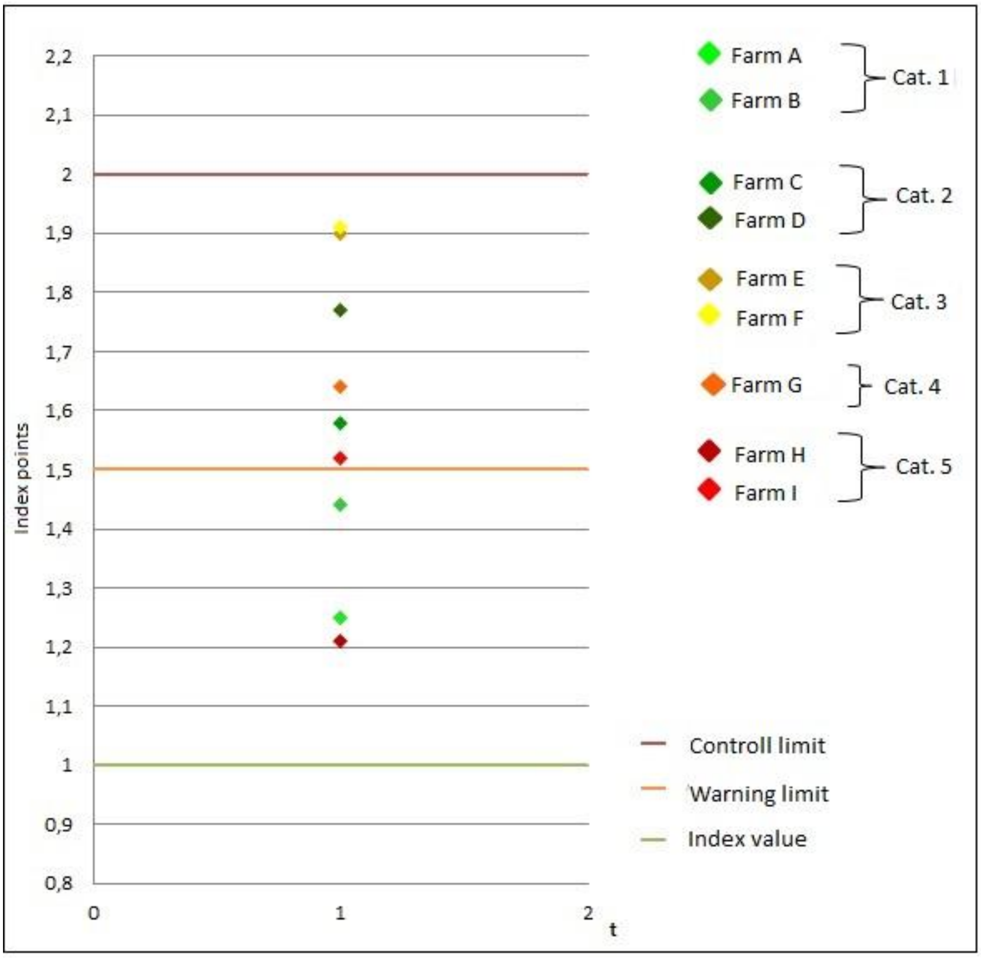


Figure 6.7: The management within the origin enterprise index

The risk indices can be applied as new key performance indicators in the customer-supplier relationship of boar fattener to slaughterhouse and can very meaningfully supplement the determined five trend curves.

In the nine pilot enterprises, suppliers with classification in category 1 exhibited clearly a better index value than operations that were previously classified into categories 3 and 4. These lay above the fixed warning limit, since several partial criteria, which constitute successful boar fattening, were not reached by these enterprises.

Table 6.12 shows results from the production-accompanying audits at the slaughterhouse with regard to behavior of the animals during the 1.5 hour resting phase before slaughter.

Table 6.12: Observations for the resting area index

	Category 1		Category 2		Category 3		Category 4	Category 5	
Operation	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Race regarding unrest in waiting house	3	3	1	1	3	3	3	1	1
Unrest in waiting house	2	2	1	1	2	3	1	1	1
Composition in the waiting house	1	3	3	1	3	1	3	1	1
Vocalizations	2	2	1	1	2	2	1	1	1
Riding up	3	3	2	1	2	3	1	1	1
Ranking fights	3	1	1	3	2	3	1	1	1
Minutes until first animal laid down	3	2	1	1	1	3	3	1	1
Minutes until all animals laid down	3	3	2	2	3	3	3	2	1
Recent skin injuries	2	2	1	1	2	3	2	2	3
Index for rest period risk	**2.44**	**2.33**	**1.44**	**1.33**	**2.22**	**2.67**	**2.00**	**1.22**	**1.22**

Differences are recognized within the enterprises. These are visualized in Figure 6.8.

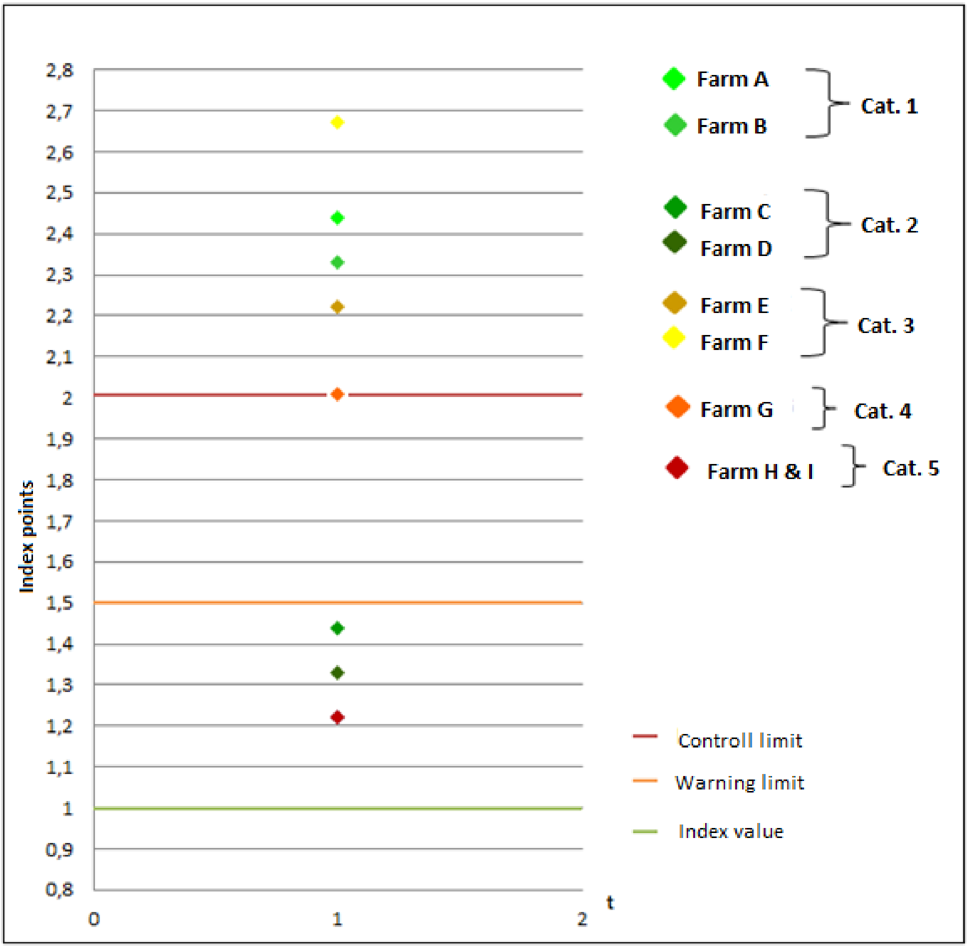


Figure 6.8: The resting area index before slaughter

The calculation of the resting area index as a key performance indicator refers to a temporally short period; however, for the avoidance of high portions of smell-changed carcasses, it is crucial information for the management sector that answers and arranges the agricultural delivery operation, as well as the slaughter enterprise. Variations in the resting area index are due to the quiescent behavior of the animals in the waiting area. This study has shown that race differences affect behavior in the resting phase. The Duroc race became calm very quickly, while some pigs of the Piétrain race frequently did not enter a rest period. They rode up more frequently and were overall more nervous. These race differences are clearly reflected in Figure 6.8. The operations C, D, H, and I clearly hold a better resting index than enterprises A, B, E, F, and G, which fatten Duroc boars. Further, groups of boars (i.e. in the transporter, as well as in the waiting area) that are sexually separated are clearly more edgy than mixed boar groups that were transported and placed in stables in the waiting area together with sows.

From table 6.13 it can be derived that Duroc boars have a positive effect on the resting area index. Also, mixed sex groups during transport and waiting have a positive influence.

Table 6.13 shows the evaluation of the carcasses based on photographs taken during slaughter. The blue marked operations slaughtered Duroc boars and the white deposited enterprises Piétrain boars.

Table 6.13: Evaluation of carcasses based on photographs that were taken during slaughter

	Category 1		Category 2		Category 3		Category 4	Category 5	
Operation identification	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Carcass classification of *good*	41.67%	33.33%	70.51%	66.67%	48.08%	13.89%	40.00%	61.90%	72.29%
Carcass classification of *medium*	45.83%	59.65%	29.49%	29.17%	48.08%	69.44%	56.52%	36.51%	27.71%
Carcass classification of *bad*	12.50%	7.02%	0%	4.17%	3.84%	16.67%	3.48%	1.59%	0%

Table 6.13 clearly shows that Duroc boars were graded more frequently into the category *good*. The majority of Piétrain boars, however, were in the category *medium*. This supports the statement that Duroc boars are calmer than Piétrain boars.

The blood testing for five diseases can be computed in accordance with the serology index by Düsseldorf (2013), which differs from calculating the risk of the management origin enterprise index. The findings are shown in Figure 6.9.

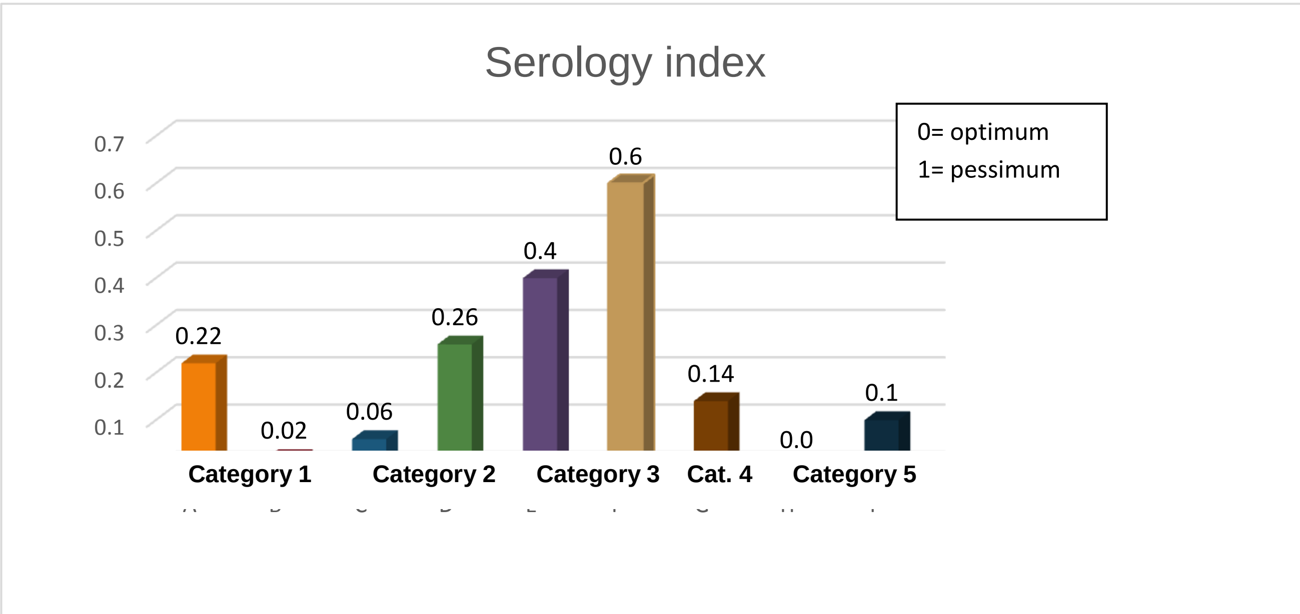


Figure 6.9: Serology index of the nine pilot enterprises

Figure 6.9 shows that enterprises B, C, and H exhibit the smallest serology index, which is evaluated positively. However, enterprises E and F from category 3 (with trends for continuous degradation) exhibit a high serology index, which is evaluated negatively and points to an insufficient health status.

Data from carcass evaluations of all 294 delivery enterprises show lung changes, pleurisy, pericardium changes, tail tip necrosis, gastrointestinal changes, front limb inflammation, front limb joint inflammation, back limb inflammation, and back limb joint inflammation. The frequency distribution of these results is presented in Figure 6.10.

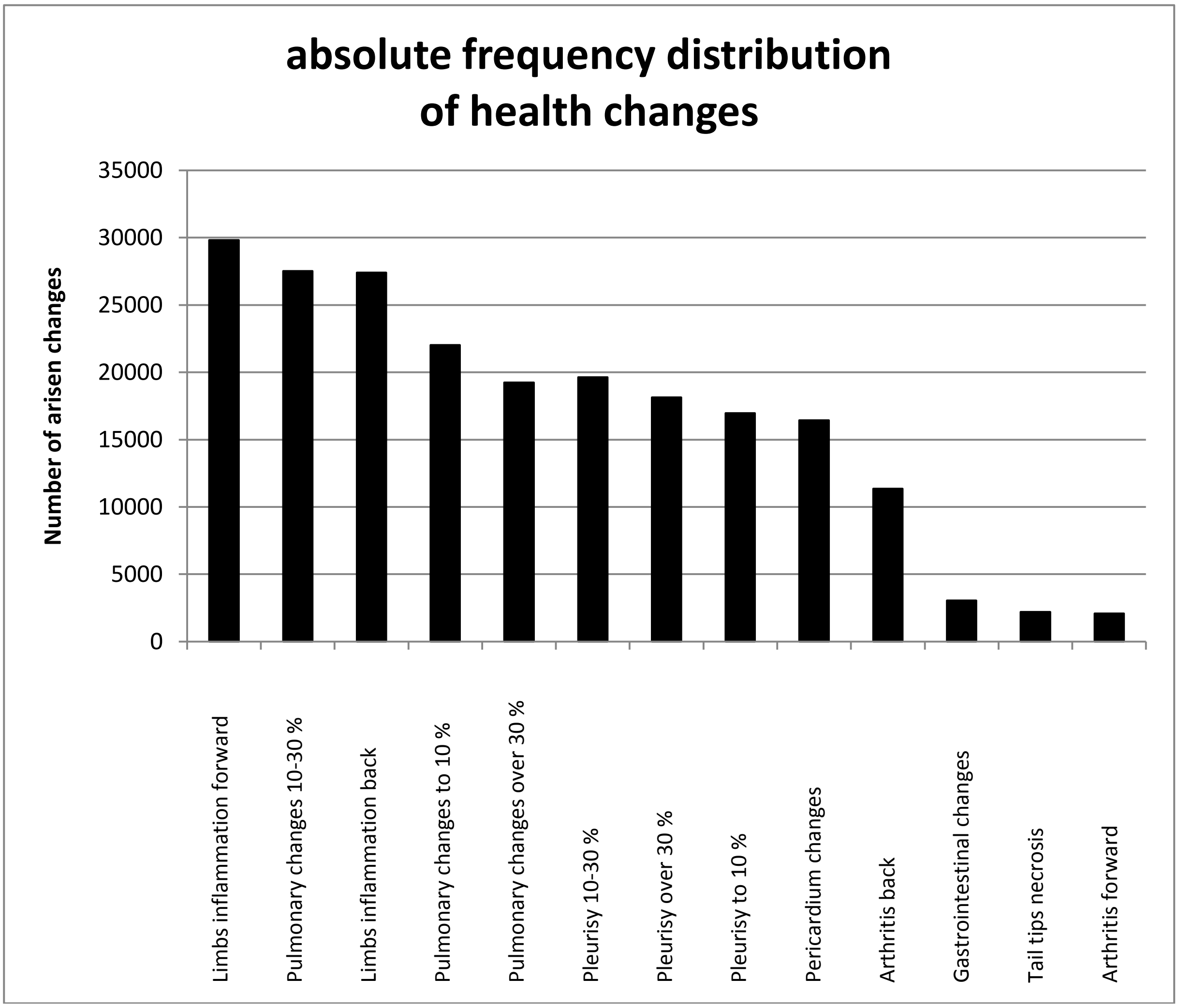
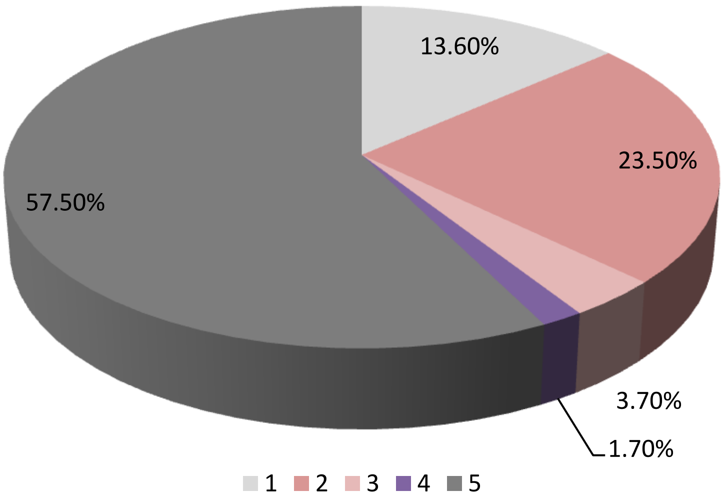


Figure 6.10: Frequency distribution of the change in health parameters determined during routine carcass screening at the slaughterhouse

With an occurrence frequency of nearly 30,000 times, front limb inflammation is the most frequently represented health change. This is followed by lung changes (10 to 30%) and hind limb inflammation. Besides front limb inflammation (2083 times), tail tip necrosis (2213 times), gastrointestinal changes (3065 times), and front limb joint inflammation exhibit the smallest frequency values.

6.5.3 Visualization of trends and risks

Figure 6.11 shows the categorizations between January 1, 2012, and November 19, 2014. A rearrangement of the enterprises to the first categorization took place.



Categories	
1= continuously inconspicuous	(slight risk)
2= trends for a continual improvement	(slight risk)
3= trends for a continual deterioration	(medium risk)
4= continuously conspicuous	(medium risk)
5= with unforeseeable fluctuations	(high risk)

Figure 6.11: Categorization of the 294 delivery enterprises for the period June 30, 2012, to November 19, 2014

Table 6.14 shows the total change of the two categorizations.

Table 6.14: Differences in the categorization due to different periods

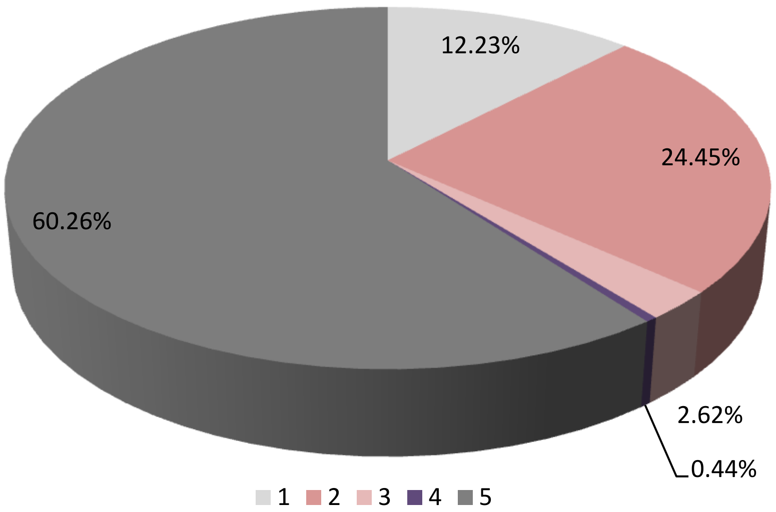
	Category 1	Category 2	Category 3	Category 4	Category 5	Sum
Number of operations from January 1, 2012, to June 30, 2014	40	53	14	8	179	294
Number of operations from January 1, 2012, to November 19, 2014	40	69	11	5	169	

Table 6.14 does not show large changes in categorization. However, it shows that 65 of the 294 enterprises stopped supplying boars to the slaughter enterprise in the period between January 2012 and November 2014.

The dataset was readjusted to exclude those enterprises that ceased their supply. The new organization of the categories for the remaining 229 enterprises are shown in Table 6.15.

Table 6.15: Organization of categorization after removing the enterprises that no longer supplied boars

	Category 1	Category 2	Category 3	Category 4	Category 5	Sum
Number of operations	28	56	6	1	138	229



Categories

1= continuously inconspicuous	(slight risk)
2= trends for a continual improvement	(slight risk)
3= trends for a continual deterioration	(medium risk)
4= continuously conspicuous	(medium risk)
5= with unforeseeable fluctuations	(high risk)

Figure 6.12: Final classification of the 229 boar supplying enterprises

From Figure 6.12 it is evident that a rearrangement of the categories has taken place (Table 6.16). However, the core categorization remains the same. Category 1 represents a small group of continuously inconspicuous enterprises (12.23%) whose risk for the slaughterhouse is estimated as slight. Enterprises that improve continuously (category 2) implicate a smaller risk for the slaughterhouse and represent with 24.45% the largest part. Enterprises that continuously worsen (category 3) and are continuously bad (category 4) represent an infinitesimal small portion of the boar supplying enterprises. Most enterprises (60.26%) are classified into category 5, which does not have a foreseeable trend. These fluctuations have a high risk for the slaughter enterprise. Table 6.16 shows the rearrangement of categorization.

Table 6.16: Rearrangement of enterprises into either better and/or worse categories

	Category 1	Category 2	Category 3	Category 4	Category 5	Sum
Number of enterprises that improved	0	0	1	3	32	36
Number of enterprises that worsened	2	18	5	0	3	28

It is evident that a rearrangement of 28% of the 229 enterprises took place. From those, 56% improved and 44% worsened. Therefore, 72 % of the operations remained in their initially assigned categories.

The human-nose method after boar slaughtering gives information about smell-deviating animals from the supplied load and represents the basis for the categorization of the enterprises. Table 6.17 shows the number of slaughtered boars per enterprise with pertinent smell-deviating animals related to the nine selected pilot enterprises.

Table 6.17: Results from the human-nose method

	Category 1		Category 2		Category 3		Category 4	Category 5	
Operation identification	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Number of slaughtered boars	52	57	78	71	52	36	118	61	85
Number of smell-deviating animals	2	1	1	0	0	1	3	1	0

From the previous categorization of the enterprises, an expectancy value could be determined. Therefore, enterprises from categories 1 (continuously inconspicuously) and 2 (with trends for continuous improvement) would be related to the following slaughters under a limit of 3.7% odor-deviating animals and close to their operating-specific average value. Category 3 enterprises, which continuously worsen, will be expected to become worse in the following slaughters. The enterprise in category 4 is expected to lie over a limit of 3.7%. For category 5, no expectancy value can be specified since this category contains enterprises that do not exhibit a trend in the relative odor deviations per slaughter.

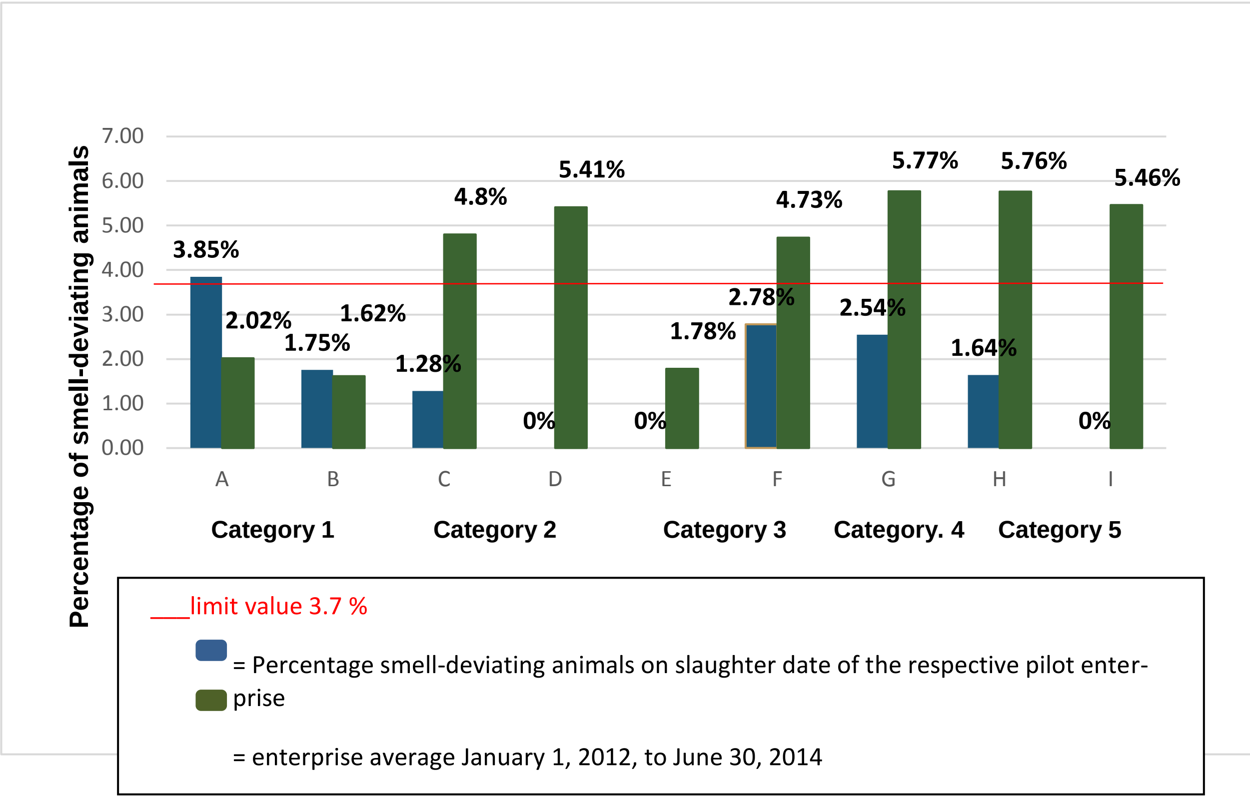


Figure 6.13: Comparison of the indicators of proportional smell deviations for the pilot enterprises with the expectancy value from retrospective data

It is striking that farm A from category 1 had an unexpected high number of boars with boar taint (3.85%)—over the abnormal odor threshold of 3.7% on the slaughter date. Farm B had 1.75% abnormal boar odor below the defined limit value of 3.7 %. Farms C and D, which were classified in category 2, showed little to no abnormal odor and as a result would be classified as category 2. Farm E, which was unpredictable and was categorized as category 3 (continuous deterioration), did not deliver any boar with an abnormal odor. However, farm F, with 2.78%, had the second highest percentage of abnormal odor boars. The only farm (G) with category 4 (continuous striking), whose rolling average was 5.77% of stinking boars, delivered 2.54% of their animals with boar odor and so was under the rolling average and below the limit of category 4 (> 4.7%). The category with an unpredictable trend (category 5) included farm H (with a low percentage of abnormal odor) and farm I (with no stinking boars).

In Figures 6.14 to 6.22 the trend curves in terms of percentage of carcasses with odor variances on delivery are shown for the nine pilot farms.

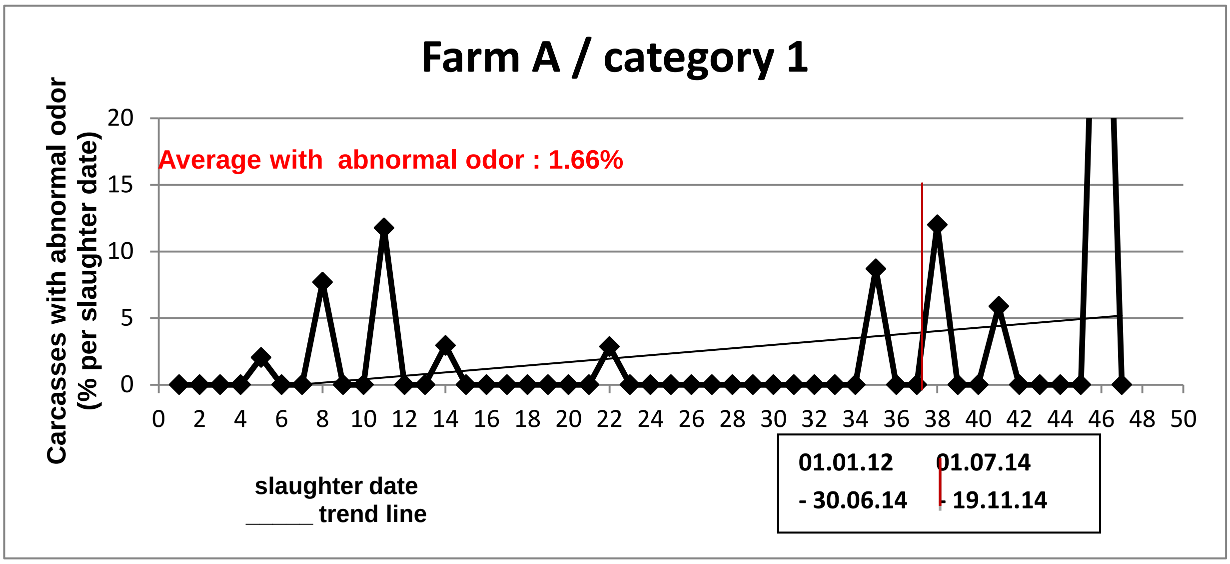


Figure 6.14: Trend curve of abnormal boar smell from farm A (given in percentage per slaughter date)

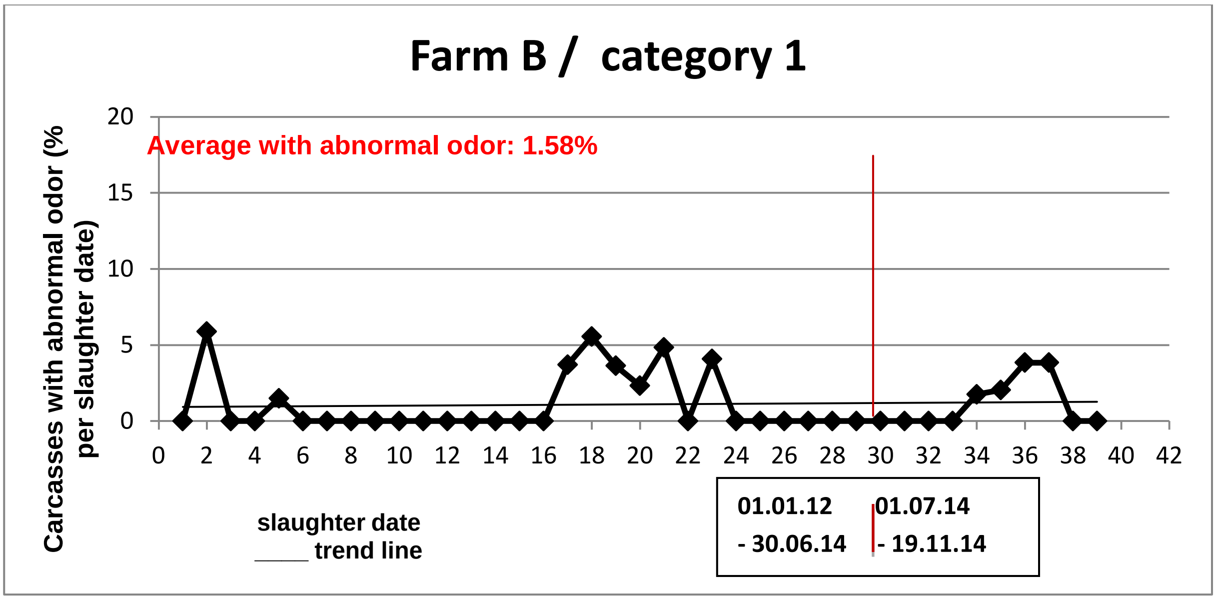


Figure 6.15: Trend curve of abnormal boar smell from farm B (given in percentage per slaughter date)

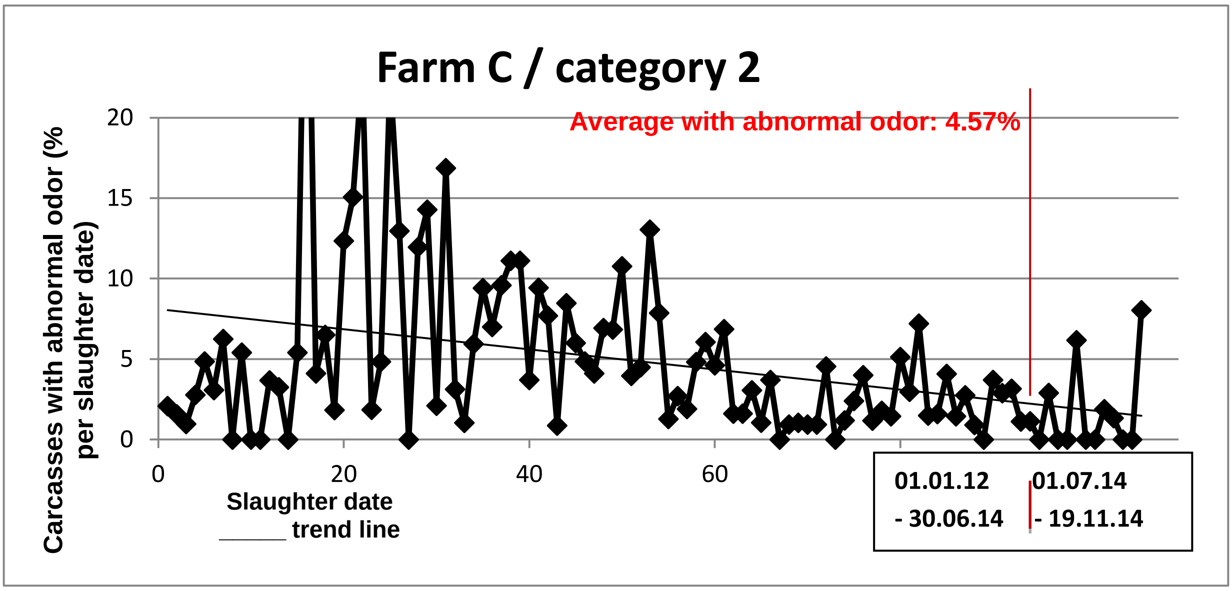


Figure 6.16: Trend curve of abnormal boar smell from farm C (given in percentage per slaughter date)

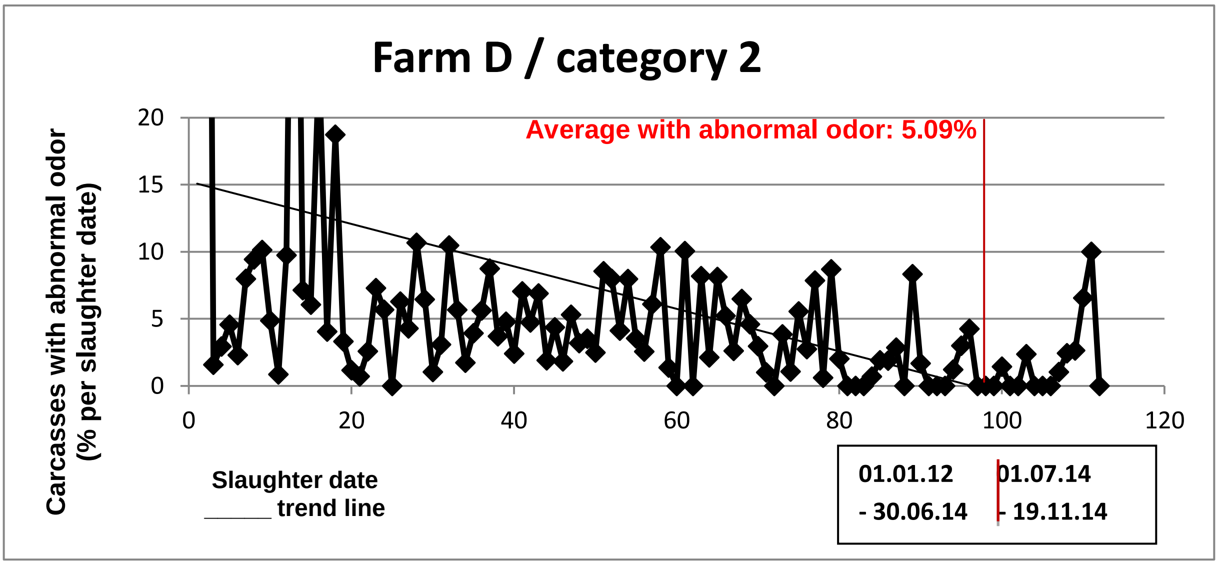


Figure 6.17: Trend curve of abnormal boar smell from farm D (given in percentage per slaughter date)

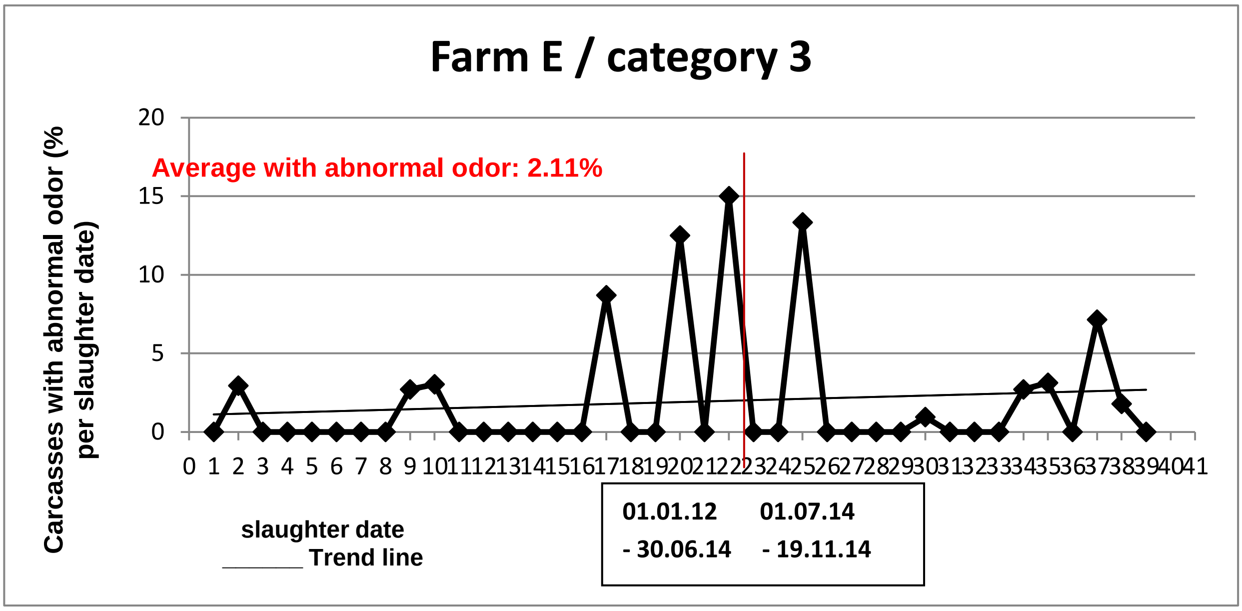


Figure 6.18: Trend curve of abnormal boar odor from farm E (given in percentage per slaughter date)

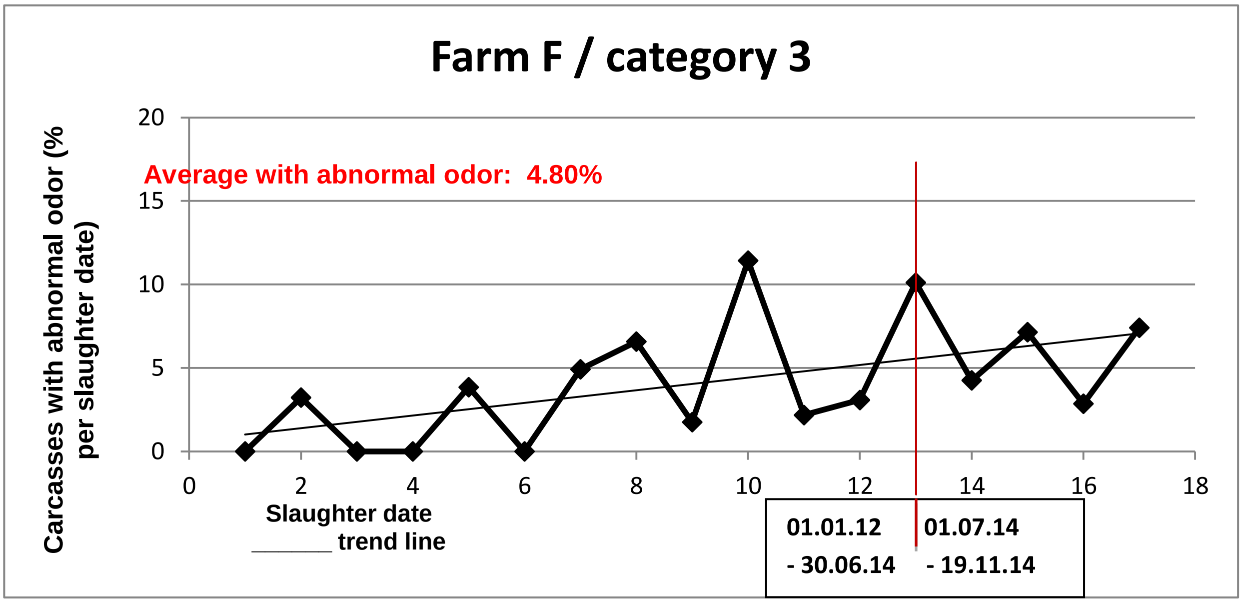


Figure 6.19: Trend curve of abnormal boar odor from farm F (given in percentage per slaughter date)

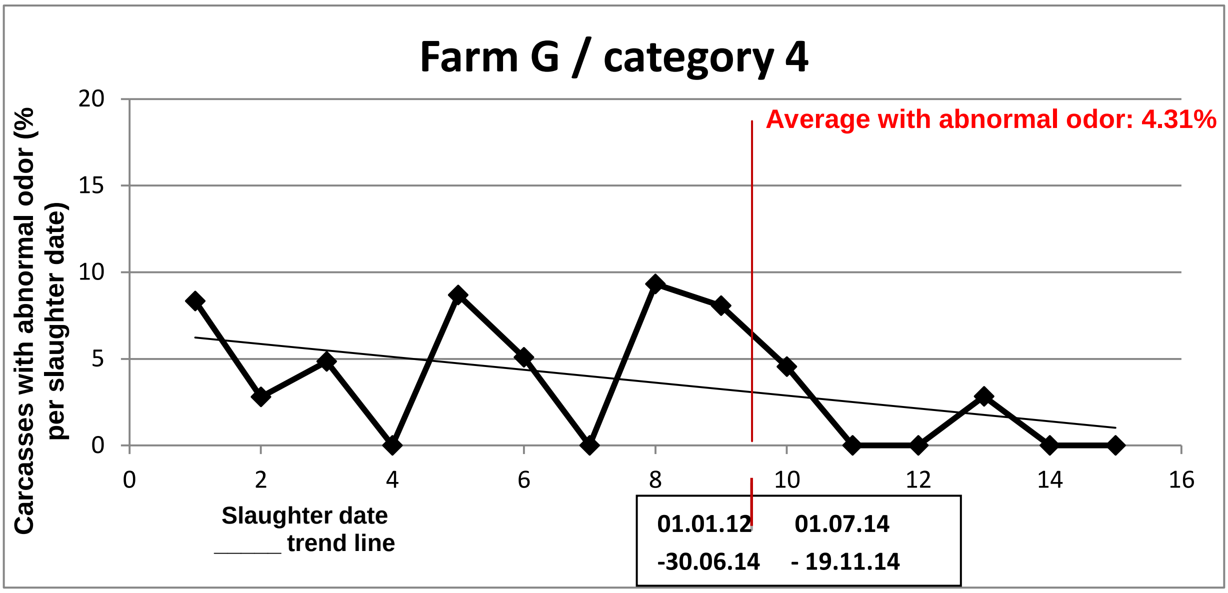


Figure 6.20: Trend curve of abnormal boar odor from farm G (given in percentage per slaughter date)

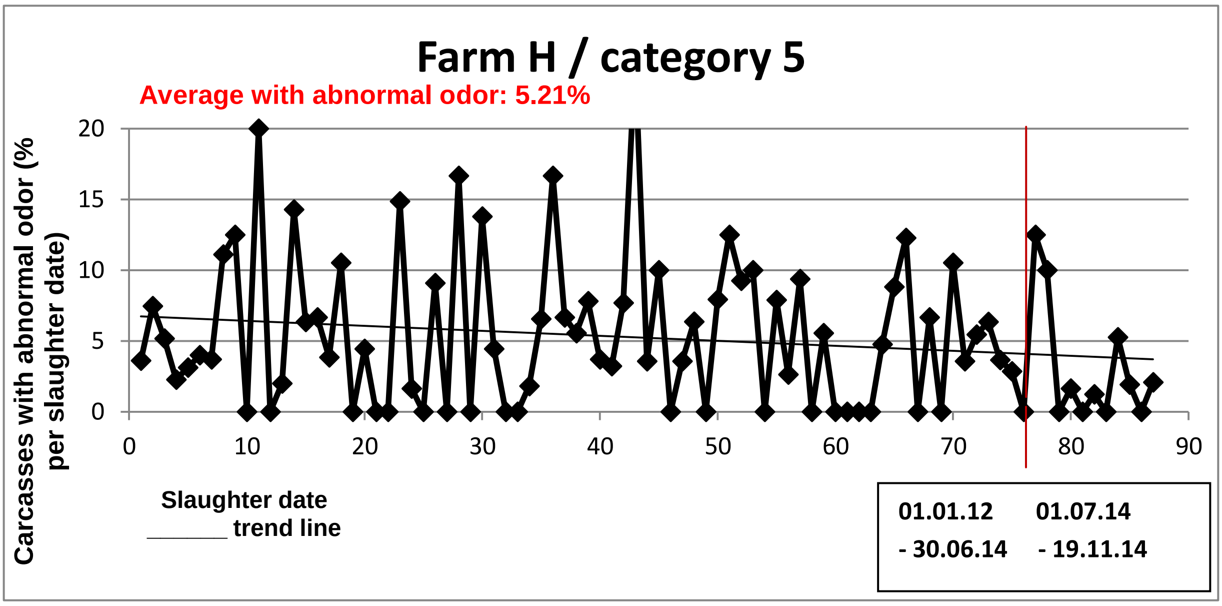


Figure 6.21: Trend curve of abnormal boar odor from farm G (given in percentage per slaughter date)

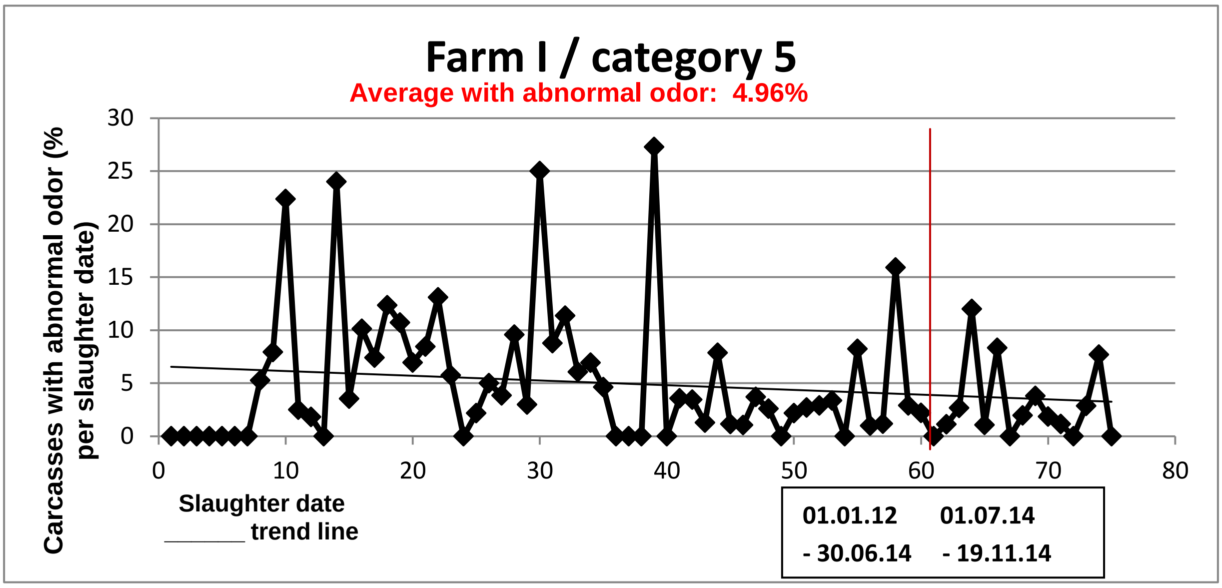


Figure 6.22: Trend curve of abnormal boar odor from farm I (given in percentage per slaughter date)

In Table 6.18 the databases for the trend curves of smell differences per date of slaughter and operation are presented.

Table 6.18: Number of bases for the analysis of the trend lines of the pilot farms

	Category 1		Category 2		Category 3		Category 4	Category 5	
Farm	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Number of boars delivered between January 1, 2012, and June 30, 2014	654	743	8304	16380	507	571	1230	3072	3625
Thereof stinking boars	8	12	400	887	9	27	71	177	198
Average number of stinking boars (%)	*1.22*	*1.62*	*4.82*	*5.42*	*1.78*	*4.73*	*5.77*	*5.76*	*5.46*
Number of boars delivered between July 1, 2014, and November 19, 2014	189	398	868	1621	726	137	532	455	869
Thereof stinking boars	6	6	19	29	17	7	5	9	25
Average number of stinking boars (%)	*3.17*	*1.51*	*2.19*	*1.79*	*2.34*	*5.11*	*0.94*	*1.98*	*2.88*
Total number of boars deliv-ered	843	1141	9172	18001	1233	708	1762	3527	4494
Thereof stinking boars	14	18	419	916	26	34	76	186	223

Total average of stinking boars (%)	*1.66*	*1.58*	*4.57*	*5.09*	*2.11*	*4.80*	*4.31*	*5.27*	*4.96*

Figures 6.14 to 6.22 and Table 6.18 show the course of abnormal odors within the period January 2012 to June 2014 and from July 2014 to November 2014. Farm A had a calculated rolling average of 1.22% until the end of June 2014. Starting in July the farm worsened, but with an average of 1.66% it remained in category 1.

The rolling average of farm B was 1.62% in the first period to June 2014 and was clearly in category 1. This improved in the second period with a rolling average of 1.58%. This farm thus remained assigned to category 1

From January 2012 to June 2014 farm C showed an improving trend. Although there were two subsequent slaughter dates with an average of 5 %, farm C showed an improving trend in the second period, reducing its average from 4.82% to 4.57%. It remained assigned to category 2.

Farm D also showed an overall improved trend and a rolling average that decreased from 5.42% to 5.09%. Nevertheless, the graph shows a clear variation in the results, so the farm had to be classified into category 5.

Farm E showed a rising trend at the end of June 2014, which assigned it to category 3. However, in the second period the farm showed an improvement, reclassifying it to category 2.

Farm G, which was continuously noticeable with regard to odor variations in the second period, showed a significant improvement in the number of stinking animals per slaughter date. In addition, this farm reduced its operation average from 5.77% to 4.31%. Because of this improvement, farm G could be allocated to category 2, with trend for continuous improvement.

During the period January 2012 to June 2014 neither farm H nor farm I showed any discernible trend regarding abnormal odors. No clear trend was evident in the second period either. These farms thereby stayed in category 5.

Statistical analysis reveals a significant ($p = 0.001$) influence of management mistakes-based organ errors on the proportion of animals with abnormal odor. From Figure 6.23 it is apparent that the larger the number of organ errors due to management mistakes, the larger is the scattering. If the number of organ errors increase by one, the probability of abnormal odors increase around three per thousand.

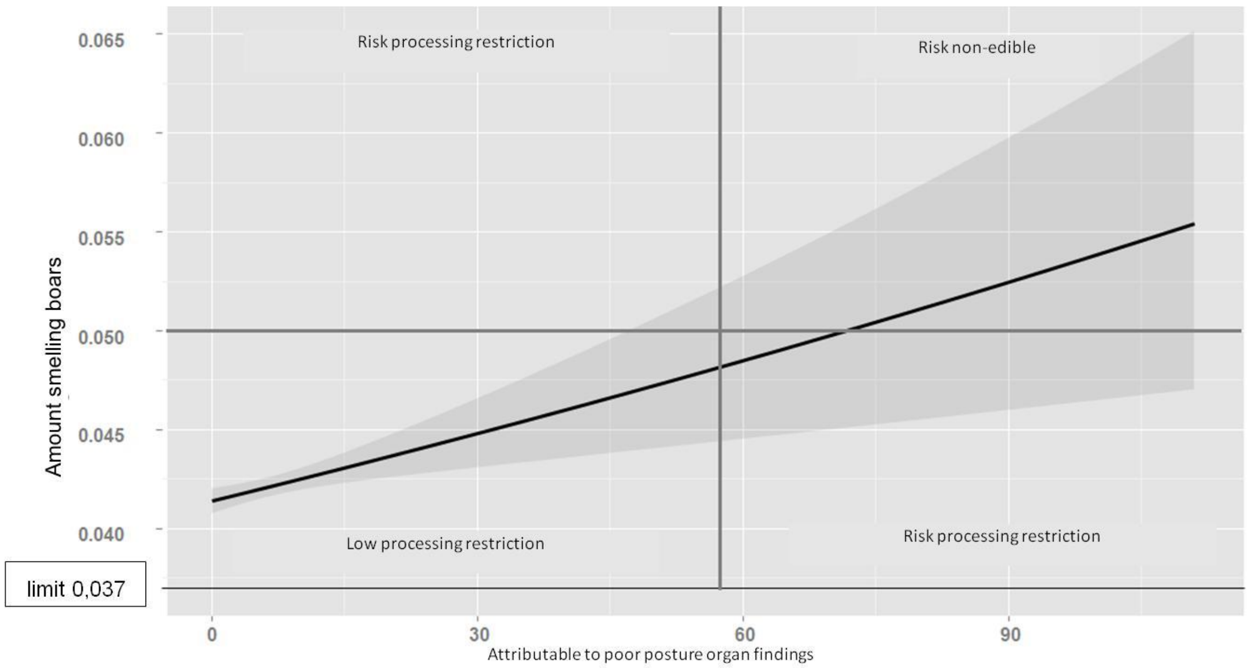


Figure 6.23: Statistical evaluation relative to organ findings attributed to husbandry defaults in the purchase to portion of smell-deviating boars

6.5.4 Proposal for the organization of operational tasks and responsibilities

The procedural model, as in Figure 6.24, represents the appropriate scope of responsibility in boar fattening of the involved participants, in order that the trend curves and key performance indicators represented before can be determined. By five retrospective procedures, information from the enterprises can be divided into categories that describe the risk of slaughter animals having an increased probability of odor deviations on the basis of a forecast. In this work a procedure is presented that describes how, from regular measurements of smell deviations at the slaughter volume, five risk categories can be specified by delivery operations. This is a task for the management of the computer resources at the slaughterhouse. In the production-accompanying procedure describing comparative and prescribing information is determined. First describing information must be present for the description of origin of the animals. In addition, partial indices count as key performance indicators, such as production characteristic numbers, stable management, hygiene measures, and illness monitoring.

This scope of duties for determining raw data is attributed to the farmers themselves, the responsible advisor, and the veterinarian. Comparative information—from comparing the indices from the waiting area and the comparison of data concerning smell deviations in the meat—makes it possible to introduce purposeful measures to the slaughter operation for their selection of suppliers, as well as supplier promotion. The prescribing information, which results from measurements and collections in grow-out, is to be understood as an if-then relationship—for example, if the delivery enterprise belongs to category 3 or 4, then the inspection frequency for the fresh meat segment would increase. Another measure would be to imply positive learning effects by a bonus-penalty system. Thus, the boar keeping enterprise gets an incentive for advancing the production of boars that do not exhibit odor deviations in the meat; and with it makes improvements to the whole management.

Phase	Retrospective procedures **after slaughtering**					Production-accompanying proceedings **before and during slaughter**							
	Predicting information					**Describing information**				**Comparing information**			**Prescribing information**
Responsibility	Category formation smell deviations	Category formation *Salmonella* status	Category formation tetracycline status	Category formation serology index	Category formation ideal-typically trend curves (Figure 2)	Production figures	Stable management	Hygiene measures	Illness monitoring	Benchmark of the KPIs	Comparison of the animals in the waiting area	Odor deviations	Bonus penalty system
Farmer						○	◊ ●	◊ ●	●				○
Consulting external services				●		◊ ●	○	○	○	○			○
Veterinarian (farmyard)									◊				○
Veterinarian (slaughterhouse)											○	○	○
Human nose slaughterhouse personnel	○				○							◊●	○
Waiting area slaughterhouse personnel											◊●		○
Slaughter area slaughterhouse personnel				◊									○
Management of computer resources slaughterhouse personnel	◊ ●	○	◊ ●	○	◊ ●	○	○	○	○	◊●	○	○	◊○
Management slaughterhouse													●
Branch-specific platform Qualitype		◊ ●											○
Laboratory									○				○

●= responsibility; ◊= performance; ○=involvement

Figure 6.24: Scope of responsibilities of the process-taken part in boar fattening

6.6 Discussion

In this work six new key performance indicators are defined. They include: Index for working with KPIs in the agricultural enterprise (for example, documentation of mast duration, age by in-stabling, feed expenditure); index for estimating possible risks; index of self-assessment; index of the outward distinctive features; illness index; Salmonella status index; index for the quiescent range to the risk evaluation within the outside system boar fattening. These indices have different functions. On the one hand, they improve the forecast for the portion of smell deviations from carcasses; on the other hand, they flaw the analysis in the supplier enterprise, as well as transport, and the phase in the waiting stable before slaughter. The focus of this project was on the retrospective view, using test data to organize the suppliers into five risk categories, as well as determine the data from production-accompanying audits. The data served for calculating the risk indices related to the management of boar fattening and the organization of transport/rest period before slaughter. Altogether, data from a catalog of 40 criteria flowed into the risk analysis.

Of the 294 boar delivering operations, 12.23% could be classified regarding boar odor as continuously inconspicuous (category 1). These enterprises control the process of boar fattening, because the distribution of the characteristic value smell deviations in the meat at the end of the process did not change, or only in well known ways or within given well known borders. Thereby, the process is quality capable (DGQ 1992). This implies a small risk for the slaughter enterprise, since it can predict that the next boar delivery will probably bring in carcasses without smell deviations (<3.7%), and permits an adjustment with firm-specific processes. Meat of boars from the load of category 1 should go particularly into fresh meat production. Of all the operations, category 2 contains 24.45%. These enterprises improved over the course of time and supplied, after a habituation time, boar batches that rarely had smell distinctive features. A small risk is also present here for the slaughter enterprise. After a learning phase these operations control the boar fattening process. Enterprises of categories 3 (2.62%) and 4 (0.44%) have a middle risk for the slaughterhouse regarding smell-remarkable boars. In all probability, the supplied boars are likely to exhibit a high percentage of smell deviation. The enterprises in these categories do not control the process, contrary to those from categories 1 and 2. Most boar delivering enterprises (60.26%) are assigned to category 5 (unforeseeable fluctuations concerning odor-deviating animals). In this case, a high risk exists for the slaughterhouse when these operations supply boars, since it cannot be predicted what will happen. The origin enterprise is not solely responsible for the above average smell distinctive features per delivery. The manner of transport and slaughter also play an important role. A study by Wesloy et al. (2015) confirmed that stress during transport and before unloading the boars lead, by different mechanisms, to higher skatole accumulation in the fat. Stress favors skatole-producing bacteria by changing the intestinal environment. An increased tryptophan availability from damaged mucous membranes lead to a higher admission of skatole from the large intestine and a smaller amplifier-off change in the liver (Wesloy et al. 2015). The androstenone level is affected by the duration of transport. Finally, Wesloy et al. (2015) stated that both transport time and the time before unloading should be reduced in order to minimize the risk of boar odor.

In the context of that project an attempt was made to keep these stressors on a similar level for all nine pilot enterprises selected (see Table S6.1).

In contrast to the study by Wesloy et al. (2015) the focus of our analysis and investigations was on the collection of health deficits. The frequency of lung evidence, pleurisies, and pericarditis as a consequence of inflammatory processes and the expression of inadequacies in the health management of the origin operation, insufficient monitoring regarding the purchase of healthy piglets, as well as insufficient air conditioning in the stables were investigated. Illnesses, those arising due to insufficient attitude systems and bad management, were also used for the evaluation. These include primarily necrosis of the tail tip and inflammation of the limbs. In addition, estimation of the health status took place from five serologically examined pathogens. Düsseldorf (2013) suggested that investigations of carcasses are meaningful and practical for providing the farmers with a more detailed feedback concerning the health status of the animals from their enterprise. That presupposes an interest on the part of the agricultural delivery operation in improving the state of health of the animals. Düsseldorf (2013) held the usual routine investigation in the clinical report concerning the organs as too nonspecific, in order to estimate the health status. The extent to which the state of health influences odor deviations in meat has not yet been shown with any evidence or numbers. However, it is accepted that health problems in the population automatically extends the duration of fattening. Since with increasing age the level of androstenone—a component that causes boar odor—increases, the probability for smell deviations in boar meat rises (Andresen 1976, Claus 1979, Bonneau 1987; Bonneau et al. 1987). As soon as judgments about boar odor emerge at the slaughter enterprise, the fattener faces a decision: Is it more economical to deliver boars that have not yet attained their goal weight—but probably do not exhibit boar odor—or is it better to extend the fattening period following recover from disease and run the risk of delivering boars with boar odor? Since a bonus-penalty system does not yet exist, there is no incentive, according to statements from the farmers, to strive for improvement regarding smell-deviating boars. However, it has been suggested that slaughterhouses not be overloaded with a bonus-penalty system and additional appraisal costs for enterprises with the trend curves 1 and 2, but allow the other operations to participate financially with higher appraisal costs. In this way, learning effects within system innovations in boar fattening could be accelerated for all participants.

The establishment and visualization of new key performance indicators play an important role in this context. The operations manager showed up very open-minded during the audits in their enterprise to improve their system of boar fattening. It is amazing that many interviewees had a wrong self-assessment with regard to the category their enterprise was in. The majority of the enterprises from category 4 (continuously remarkably regarding smell deviations) adjusted to supply boars to the slaughter enterprise. This could be the expression for the fact that they recognized that they do not control the process of boar fattening.

The correlation ($p = 0.001$) between the clinical reports concerning organs, which can be attributed to husbandry errors (tail tip necrosis and limb inflammations), and smell deviations state that operations having good management related to the husbandry show a prevalence for fewer smell-deviating animals. The higher the number of deficiencies, the larger the dispersion becomes. This is attributed to the fact that there are still different parameters which affect the occurrence of boar odor. The accumulated occurrence of boar smell is seen as a multifactorial problem, which is not attributed to individual parameters (Götz et al. 2009). The occurrence of boar odor is the result of different factors of influence, which can be different with each origin enterprise. Inflammation of the limbs and tail tip necrosis are signs of stress within the herd. Limb inflammation can occur from the more active behavior of boars—contrary to castrated boars or sows—including increased riding up or rank combat behavior. Conceivable causes for tail tip necrosis are a too high animal density and immune stress (Fritschen & Hogg 1983; Plonait 2004).

From the retrospective data analysis and the results of the production-accompanying audit, it is recognized that different risk levels for smell distinctive features, as well as for medical organ evidence, is supplied to the slaughterhouse with each boar delivery. By a retrospective data analysis, the slaughterhouse has the possibility of making a predictive value for the deliveries. In this way decisions during the sorting process at the slaughter line can be made more surely. The battle enterprise, which participated in this project, had already tried to arrange the waiting area so that the animals could settle down as quickly as possible. In the first instance a restful unloading of the animals is important. Further, on arrival in the waiting boxes the animals could eat some grain maize. Relaxing music and a twenty-minute water irrigation should also exert a positive influence on the lying habits of the pigs. Last but not least, green light had been installed on their way to the anaesthetization area. This has a calming effect. In this study it was stated that race-specific differences exist in the quiescent behavior of the animals. While Duroc boars were quick to relax, Piétrain boars seldom laid down. Here it is valid to examine a priori information concerning the race of the animals, which can change processes in the waiting area so that Piétrain pigs can also find better peace. The edgy behavior such as riding up and rank fights can, like AHAW (2004), have a negative influence on meat quality. To be able to routinely take up these production-accompanying data at the slaughterhouse, noise sensors and image processing programs must be installed in the waiting area. This data should be passed on to the EDP of the slaughter enterprise.

For a safe risk estimate, a combination of retrospective data analysis and production-accompanying audits is recommended. Factors of risk show themselves both with view of the areas of responsibility of the slaughter operation and the delivery enterprise. Learning effects on both sides thus adjust themselves faster. The conversion to boar fattening is considered as a system change, which provokes all participants of the meat producing chain. Not only are farmers involved, but also advisors, farmyard veterinarians, veterinarians in the slaughterhouse, human nose personnel at the slaughterhouse, personnel in the waiting area and slaughter area, and the management and EDP staff of the slaughterhouse, as well as the branch platform Qualitype and also laboratories. Here the described proposal of the definition of additional scope of responsibility for the processing participants in boar fattening points out to what extent participants can contribute with the use of new KPIs to an improvement in the process. Only with good cooperation and information forwarding on all stages of the meat production chain can a positive learning success be induced. Already Schütz (2008), Ellebrecht (2008), and Slütter (2013) stress that information exchange between customers and suppliers is indispensable for success in learning. Quality and the degree of enterprise-spreading cooperation among fattening, slaughtering, and processing can be pointed out by the Six Sigma approach, as shown by Klauke and Brinkmann (2009).

For the organization of this information exchange, the AMOR model plans the formation of alliances among the different participants of the chain who plan, realize, and finance all together the risk-oriented test strategies. According to Petersen et al. (2013) and O'Hagen (2014), cooperation provides for both sides, suppliers and customers, a benefit that is supported from neutral private-economical or public organizations. Such cooperation was implemented in 2010 in North Rhine/Westphalia through the new project "Schlachtdaten" (slaughter dates) of the Westphalia-Lippe Agricultural Association (WLV) and the office of a federal state for nature, environment, and consumer protection (LANUV) of North Rhine/Westphalia. The project entailed the collection of original data—the weighing and classification of slaughter pigs—in cooperation with the operation B. & C. Tönnies in Rheda-Wiedenbrück. Slaughter data are thereby fed, uninfluenced by third parties, directly from the calibration ranges of the weights and the classification devices over a "black box" into a database from the LANUV. Farmers receive entry and can access the data directly (LANUV 2012). The extension of this database around measured values of odor deviations would be a possibility in the future for seizing and evaluating the existing retrospective data and supplementary survey data from the production-accompanying audits. In the context of the project FIN-Q.NRW, how system changes could be supported technically and organizationally has already been suggested. Development work for planning and decision support systems for risk management within this range began during the last few years (Schulze-Geisthövel 2012). One obligating vote criterion for the organization "Initiative Tierwohl", which starts in 2015, is represented by the fattening of young boars. This places a further incentive for quickly obtaining learning effects in the boar fattening system.

6.7 Supporting Information

Table S6.19: Characteristics of the nine pilot farms

	Category 1		Category 2		Category 3		Category 4	Category 5	
Farm identification	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Genetics	Piétrain	Piétrain	Duroc	Duroc	Piétrain	Piétrain	Piétrain	Duroc	Duroc
Distance to the slaughterhouse (km)	36.3	70.2	112.2	76.9	70.2	66.1	76.2	89.7	86.3
Travel time of the transporter	1.5h	2h	2h	ca. 2h	3h	1.5h	2h	1.75h	2.25h
Boars delivered between January 2012 and November 2014	2573	1141	9172	18001	1233	708	1762	3527	4494
Boars with noticeable odor	58	18	419	916	26	34	76	186	223
Rolling average to June 30, 2014	1.80%	1.62%	4.82%	5.42%	1.78%	4.73%	5.77%	5.76%	5.46%
Rolling average to November 19, 2014	2.25%	1.58%	4.57%	5.09%	2.11%	4.80%	4.31%	5.27%	4.96%
Wait time in the relaxation area	1.5h	1.5h	1.5h	1.5h	1.5h	1.5h	1.5h	1.5h	1.5h
Stun method	CO_2	CO_2	CO_2	CO_2	CO_2	CO_2	CO_2	CO_2	CO_2

In the following Tables (S6.2 to S6.7) the parameters are listed, which are part of the management premises of origin index. These were made to make calculations categorized and defined.

Table S6.20: Classification parameters for the index for working with key performance indicators

Parameter	Category	Definition
Daily weight gain (fattening)	1	Known
	3	Unknown
Boar fattening period	1	Known
	3	Unknown
Initial age	1	Known
	3	Unknown
Move out age	1	Known
	3	Unknown
Initial weight	1	Known
	3	Unknown
Move out age	1	Known
	3	Unknown
Feed conversion	1	Known
	3	Unknown
Animals lost in total	1	Known
	3	Unknown

Table S6.21: Classification parameters for the index for assessing potential risks

Parameter	Category	Definition
Temperature fluctuations	1	Controlled
	3	Unknown
Group size	1	Small groups
	2	Medium groups
	3	Large groups
Ventilation cleaning	1	Regularly
	2	Not regularly

Parameter	Category	Definition
	3	Not at all
Water cleaning	1	Regularly
	2	Not regularly
	3	Not at all
Feed cleaning	1	Regularly
	2	Not regularly
	3	Not at all
Stable cleaning	1	Regularly
	2	Not regularly
	3	Not at all
Stable disinfection	1	Regularly
	2	Not regularly
	3	Not at all
Implementation of hygiene measures	1	Yes no exceptions
	2	Some exceptions
	3	Many exceptions

Table S6.22: Classification parameters for the index of self-assessment

Parameter	Category	Definition
Self-categorization	1	Correctly classified
	2	Too bad classified
	3	Too good classified

Table S6.23: Classification parameters for the index of external abnormalities

Parameter	Category	Definition
Reddened eyes	1	Not recognizable
	2	Recognizable
	3	Highly recognizable
Smeared eyes / nose	1	Not recognizable
	2	Recognizable
	3	Highly recognizable
Skin lesions fresh	1	Not recognizable
	2	Recognizable
	3	Highly recognizable
Skin lesions old	1	Not recognizable
	2	Recognizable
	3	Highly recognizable
Dirty	1	Not recognizable
	2	Recognizable
	3	Highly recognizable
Tail wounds	1	Not recognizable
	2	Recognizable
	3	Highly recognizable
Wounds on ears	1	Not recognizable
	2	Recognizable
	3	Highly recognizable
Foundation problems	1	Not recognizable
	2	Recognizable
	3	Highly recognizable

Table S6.24: Classification parameters for the disease index

Parameter	Category	Definition
Disease		
PRRSV	1	Negative
	3	Positive
APP	1	Negative
	3	Positive
Swine influenza	1	Negative
	3	Positive
PCV2	1	Negative
	3	Positive
M. hyopneumoniae	1	Negative
	3	Positive
Haptoglobin content	1	Acceptable
	3	To high

Table S6.25: Classification parameters for the index of Salmonella status

Parameter	Category	Definition
***Salmonella* status 1**	1	Good
***Salmonella* status 2**	3	Bad

7 General conclusions

7.1 Introduction

The unpredictability of the future is a feature in the development and introduction of complex innovations. The success of innovation processes depend on both market developments and society and on the behavior of other important participants in the innovation process. This increases the uncertainty in the innovation process in view of the growing requirements of the customers, as well as progressive specialization that requires increased expenditure of information and votes from all participants (Bokelmann et al. 2012). In the past years the perspectives about the responsibility and action structures of the individual agricultural enterprise has shifted to a sector rather than a complex system of different value-added chains (Bokelmann 2009, McIntyre et al. 2009, Petersen et al. 2014). The farm-to-fork and fork-to-farm approach is an expression of this viewpoint (Schulze Althoff 2006, Ellebrecht 2008, O'Hagan 2014, Düsseldorf 2013). Against the background of this massive organizational chain-oriented view, the meat industry in Europe is currently preparing itself for profound changes. It is characterized by a conversion to boar fattening, a reduction in antibiotic treatments during piglet production and fattening operations, as well as renouncement of tail docking in the first days of the pig's life. It is common that all changes require system innovations. In changing very complex processes, the three aspects of humans, technology, and infrastructure have to be considered. Concrete forecasts can only be made for individual stages of the value-added chain where consequences can be expected if individuals or groups of plant managers decide for or against boar fattening or tail docking; while antibiotic use can be reduced by new procedures in health care. System innovations in this context mean, without exception, a contribution from all participants along the entire value-added chain. It requires a meaningful combination of fair animal husbandry systems, general knowledge, agreed enterprise-wide self-monitoring, and benchmarking.

In the following section the answers that were derived from the results of the five partial studies of this work are presented for the three research questions that were initially posed.

7.2 Answers to the research questions

1. Why are system innovations envisioned in the pork-production chain?

a) Within the last few years social pressure on all participants (animal keepers, slaughterhouses, meat processing etc.) in the pork value-added chain has strongly increased, which has forced a rethink in the ways that pork is produced.

Animal well-being has, in recent years, become an international topic. The Netherlands and Denmark have quality leadership in this domain. From the empirical studies of this thesis it became clear that livestock farmers and responsible federations in Germany had, at first, a rather cautious attitude in renouncing piglet castration, introducing the countrywide antibiotic database(s), and renouncing tail docking. There were, nevertheless, clear signals from science and from international meat companies—also in Germany—that boar fattening, unabridged and

uninjured tails, as well as pork without antibiotic residuals, are indicators for customer-oriented animal production and could be regarded as an expression of animal well-being.
In recent years animal well-being labels have been developed from initiatives such as *Action Animal Welfare* (Aktion Tierwohl) from the Westfleisch company (Beuck 2011) and *Better Life* (Beter leven) from Albert Heijn (Steverink 2011). In addition, the Dutch have another program named *Sustainable Pig Production* (nachhaltige Schweinefleischerzeugung). This program goes well beyond the aspects of animal well-being and animal health; at the same time it also comprises measures to better protect humans and the environment. Moreover, there are still the animal well-being labels of the Göttinger Initiative Group of Animal Welfare Label (Göttinger Initiativgruppe Tierwohl-Label) from the German Animal Protection Association (Deutscher Tierschutzbund) (Schröder 2011), as well as the countrywide *Initiative Animal Welfare* (Initiative Tierwohl 2015) from the food retailing and supplying chains, amongst others. In the last years monetary contributions have been available for networks of enterprises and scientists that develop, test, and evaluate measures in the context of competitive projects with the aim of improving animal health and husbandry conditions.

b) System innovations can place competitors and individual trendsetters in demand and provide positive experiences in practice. These innovations have shown that:

- renouncement of piglet castration with subsequent boar fattening is economically possible,
- renouncement of tail docking does not lead to higher losses or danger of injury in well led piglet producers and mast enterprises, if the operating-specific factors of risk are recognized and purposefully eliminated, and
- the reduction of antibiotic use is to a reasonable amount possible if production-accompanying health care investigations for certain infections are recognized in time and the inoculation prophylaxis administered in a timely fashion.

c) Market partners together have seized the initiative to introduce changes.

All market partner initiatives are started together in order to increase the propensity to invest in change as a response to attitudes about the food-supplying animal within the husbandry system and production procedures, as well as the organization of health and quality management measures.

2. What measures are necessary so that these are successfully implemented and/or accomplished?

a) Bundling of coordinated measures in the value-added chain (matrix with 69 individual measures, categorized according to three dimensions and four elements of system innovations)

If the individual results of the five partial studies are united, then one comes to the conclusion that system innovations can only be realized if a coordinated interaction is reached by humans/software, technology/hardware, and infrastructure/orgware. Table 7.1 shows the new products, services, and components, as well as competencies that are, in this context, discussed with experts in the empirical studies and which are suggested by the results of the experimental work in this study.

b) Automation of production-accompanying measurements and testing methods

With regard to the conversion to boar fattening, only a few methods are available to proof boar odor (human nose), but they are costly and not yet applicable as measuring procedures. The slaughter and processing enterprises are taking part in developing the measuring methods, which must be intergratable into these processes. Currently, these methods include various online measuring procedures that ascertain noise and movement changes in the animals and injuries such as streaks and inflammation (image processing, thermal imaging cameras). These methods of the precision livestock farming can be combined with methods of quality management for estimating risks (FMEA, HACCP) or process capability, as well as process control (control chart principle). They also interconnect with more complex team-oriented methods such as Six Sigma (Borrel et al. 2001). Computer-aided systems for automated animal recognition, feeding, and animal monitoring supply an abundance of technical data, which can be fed from an internal management system into a central quality management database. The first proposals were compiled for pig production (Slütter 2013, Ellebrecht 2008, Schulze Althoff 2006). The trend in management and software leads to a comprehensive system approach. The concerns here are purely for meaningful automated linking and processing, the use of process and relevant operating data, as well as their automated and standardized import and export. This data is at the user's disposal and is independent of time and location and assists in the optimization of husbandry and process conditions.

A solution to a common European basic standard is discussed, which provides the elements of operational data acquisition, regular audits and laboratory analyses, uniform analysis, and analysis standards, as well as database and a certificate.

Harmonization to a certain degree (e.g. a basic standard) has advantages regarding overcoming any restrictions of market access. Further cost advantages can be generated. A common database and/or the exchange of data over interfaces would facilitate communication of the participants between the systems and possibly also with veterinarian authorities (Czekala et al. 2013). The steps for the harmonization and standardization of these procedures are still uncertain; however, the necessity is clearly recognized by international enterprises of the value-added chain. A neutral presentation of committees from the normative, strategic, and operational levels facilitate the vote and lead more rapidly to the goal of implementing "Health-proven Europe" as a basic standard in practice. Thus, basically a new innovation approach is being developed for the advancement of animal husbandry and, in particular, pig husbandry, because computer-aided stable systems make species-appropriate farming possible with simultaneous intensive single animal care and large group management. The production rhythm is no longer determined by the work rhythm of humans, but rather by the individual rhythm of the animals. Thereby, animal well-being and performance of the pigs are improved. Also, humans are freed from the close connection with the operational sequences. This not only improves the working conditions, but also makes it possible to center the stable systems consistently on the requirements of the animals (Schön et al. 2003). The target of precision livestock farming, therefore, includes linking, organizing, regulating, and supervising the interaction among humans, technology, and infrastructure better than currently available.

c) Organization of ICT-supported services

Instrumentation innovations (e.g. electronic nose) are a meaningful extension in certain domains of an already existing chain where information, communication, and consulting concepts are paramount. Thereby, the entire value-added pork chain and the appropriate marketing statements can be viewed by the customers as well as the consumers. The service platforms can, therefore, have a linking function among the three innovation categories (hardware, software, orgware) (Ellebrecht 2008, Düsseldorf 2013). To achieve these aims the livestock must have a high health status and food safety and quality must improve continuously. It was shown in the partial studies in this thesis that cooperative livestock marketers and producer communities have taken on this task by means of a quality meat program. Here, already at the runtime, the cooperative projects have formed successful alliances between agricultural enterprises and providers of appropriate support and advisory services, as well as the science community (Schütz 2009, Ellebrecht 2012, Brinkmann et al. 2011), and have established new business models. This offer will constantly extend in the future due to the further tasks in the audit management and in the monitoring, in order to be able to demonstrate the quality and risk management achievements of the entire value-added chain (Düsseldorf 2013). As a welcome side effect the interviewed experts of the industry acknowledged that the continuously stored production-accompanying data from the entire enterprise about quality and health management can also be used in the case of a crisis; for example, during an epidemic outbreak the complete proof of traceability and decision making processes can be effectively supported (Slütter 2013).

3. How can these measures be optimally converted so that they bring lasting success?

a) Simulation models can provide prognoses for the consequences of the conversion processes

With the complex conversion and change processes regarded in the work, not all influencing factors can be determined by means of experimental studies. In this case it is very helpful to describe a theoretical model of biological-technical and organizational coherencies and convert this word model into a mathematical and finally into a simulation model (Raab 2011, Kreyenschmidt 2003, Blaschzyk 1995, Künneken 1991). Forecasts—in the context of simulation scenarios and simulation runs—can be derived and / or visualized by regarding the consequences from the measured changes in production conditions and processes. The data concerning resistance propagation or the growth and health status of the pigs from different production conditions, obtained in the experimental studies, serve for that issue. Existing simulation programs have to be developed further so that they can be used for the planning and development of new testing strategies. Here it concerns the systematization of instruments and methods for risk identification. On the one hand, simulation programs should serve researchers in the design of experiments and the running of retrospective analyses; on the other hand, they should serve as teaching programs for the advisors of farmers in order to clarify relations and to support strategic planning (see Figure 7.1).

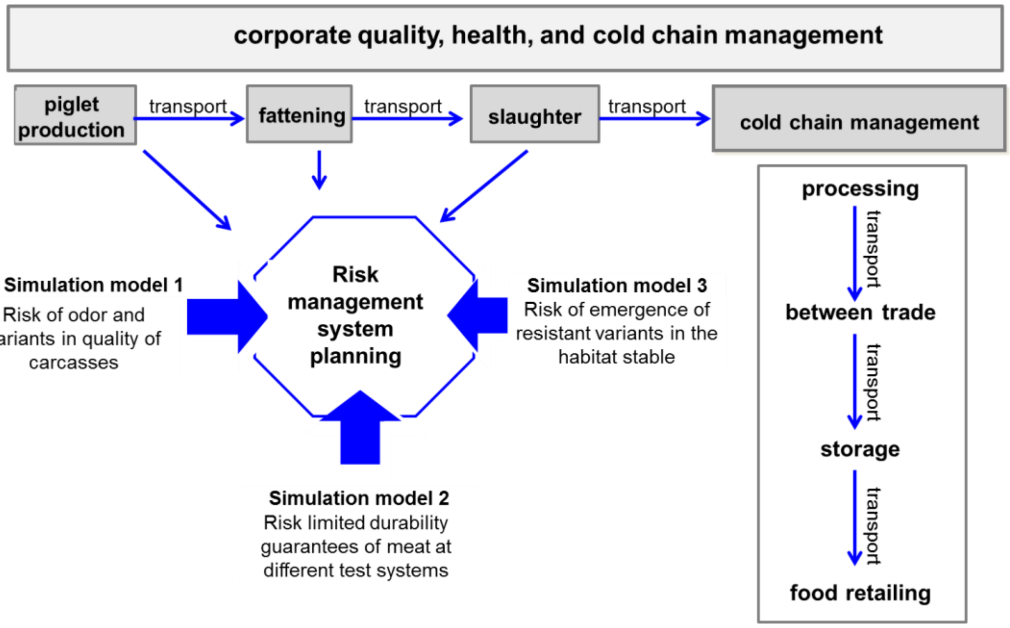


Figure 7.1: Prognostic information for strategic planning of risk management in the meat value chain

b) Using virtual quality management techniques for selecting suitable test parameters and test strategies

Also under consideration is the provision of methods with which virtual quality management (QM) techniques can be integrated when planning the measurement and sorting processes as applied to process simulations. In addition, methods for the statistical experimental design and the statistical process steering element are modeled with the use of online measuring procedures and integrated into simulated, quality-referred effect relationships. Thus, in the planning phase in a complex enterprise it is already possible to select practicable communication for the sequenced testing methods, as well as enable virtual optimization with models, and define a strategy of process guidance. In this context methodical theoretical approaches of the virtual quality management are of interest (Weckenmann & Bookjans 2009). The vision-to-model is pursued with the help of different tools of the virtual reality innovation measuring processes during the planning phase and is virtually controlled (before commencement of production) by well-engineered quality automated control loops. The goal is to guarantee an unimpaired production process without delays during the slaughtering process. In the virtual quality management, automated control loops are already adapted and quality and/or cost-optimized in the early planning phases and simulated to the respective processes.

c) Use of a common knowledge platform for setting up a risk management system with data and empirical values from practice, as well as models and planning tools from science

Those instruments that are already partly in practice for supporting the planning of risk management of network coordinators can be assigned by the task ranges and are represented in Figure 7.2.

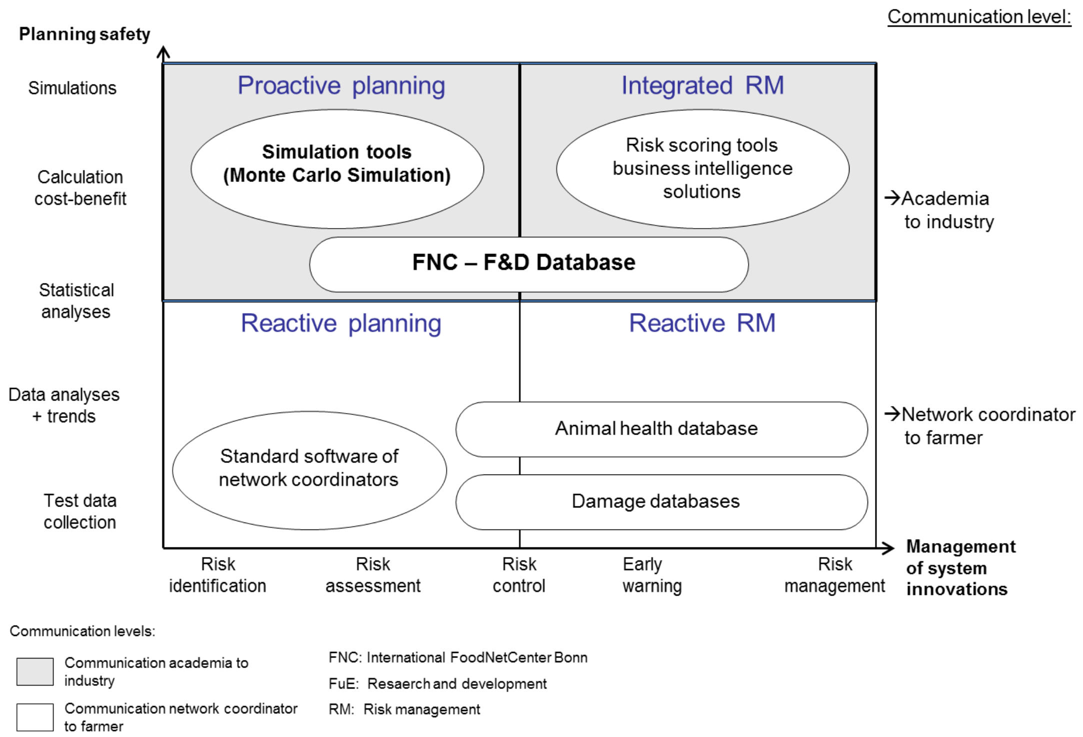


Figure 7.2: Information and communication tools (ICT) for integrated risk management

The process of implementing system innovations such as the conversion in the meat industry sector is extremely complex. With renouncing piglet castration a reorganization to boar fattening is required. In addition, the adherence to further demands such as reduced use of antibiotics and observing animal welfare standards in husbandry, transport, and slaughter are required. Due to this complexity, it is hardly imaginable in a simulation program. Therefore, it is suggested that the two levels of quality communication—between network coordinators and operations of the value-added meat chain, as well as those between economy and science—are conflated into an interdisciplinary risk management system. The partly already established common research and development database conceived within the FIN-Q project can support the integration. An interdisciplinary risk management system for any shifting or disturbance within the value-added pork chain represents a versatile, usable knowledge platform to accelerate the development and realization of system innovations.

Table 7.1 provides an overview of partial innovation aspects within the different domains.

Table 7.1: Overview matrix of individual measures classified by three dimensions and four elements of system innovations (own representation)

Dimensions Elements	**Human/Software**	**Technology/Hardware**	**Infrastructure/Orgware**
Product	**Immaterial product (production-accompanying services):** - Execution of the human nose procedure; - Sampling with entry, intermediate, and final inspections in the value-added chain; - Auditing enterprises in the sense of weak point analyses; - Conformance testing in the sense of the observance of standards and norms (e.g. animal health standards, defaults relative to husbandry and transport of animals, StallTÜV, animal well-being standards); - Prognosis and trend calculations.	**Material product:** mobile laboratory **Transponder technology:** - For identification and traceability of animals, animal groups, carcasses, cuts, and batches. **Sensor technology:** - Monitoring temperature, air humidity, noxious gases in the environment of animals; - Detection of smell deviations in meat (electronic nose); - Monitoring movement and noise profiles of animal groups. **Image processing technology:** - Sex recognition at the slaughter line; - Recognizing old and new injuries on an animal's body and/ or carcass. **Microbiological and biochemical analysis technologies:** - Testing kits for serological investigation of blood parameters; - Testing kits for residue analytics in meat juice, saliva, and urine; - Rapid tests for local diagnosis by measuring health parameters. **Process control technologies:** - Assortment of animal groups and carcasses by sex, weight, and health status; - Stable climate control.	**Information-technology databases:** **Individual company (standard encoder, certification enterprise, system provider)** - QS antibiotic database; - QS salmonella database; - QS audit database; - Management programs. **Cooperatives as operator companies** - TiGA database **Public organizations as neutral contact points between market partners and official authorities** - BlackBox; - HI- animal database population register; - Official antibiotic database. These offer free of charge or chargeable access to new platforms and databases for different target audiences or registering the labeling of products

Dimensions Elements	Human/Software	Technology/Hardware	Infrastructure/Orgware
Service	- Coordination of enterprise-wide operational sequence in the health and risk management; - Coordination of audit and monitoring activities within value-added chains; - Coordination from vote processes to the continuous improvement of an outside health and risk management; - Visualization of KVPs, trends, portfolios, control charts; - Analysis of measured values within the laboratory or production-accompanying process; - Consultation of enterprises during the system migration; - Production-accompanying achievement and sanitary control.	- Collection, storage, and processing of measuring and analysis data; - Availability of memory space and computer capacities; - Technical service for internet portals and target group-specific apps.	- Supplying of data and information from research and development databases of universities, as well as F+E platforms; - Supplying of data and information from knowledge bases of agencies responsible for the project; - Border-spreading knowledge transfer from expert workshops and topic workshops; - Network coordinators; - Brokers between agricultural enterprises and slaughtering enterprises.
Components	- Public-private transport-waiting stable audit of delivering enterprises with boar fattening; - Operating audit in animal-keeping enterprises; - Internal and external audits within the value-added chain; - Coordinating test strategies in the sense of the AMOR approach; - Evaluation of joint animal well-being achievement of the value-added chain; - Chain-oriented evaluation of investments for the observance of health and animal well-being standards.	- Information and communication systems between partners of the value-added meat chain; - Rapid tests and analysis methods for monitoring systems; - Technical components for animal observation and collection of risk factors in the environment of animals.	-*Initiative Animal Welfare* (Initiative Tierwohl) (economy-driven organizational structure); - Sector-specific information and service organizations; - Research and development platforms.
Competences	- Understanding and application of QM principles (e.g. continuous improvement process); - Understanding and interpreting KPI related to different production processes and sections; - Training motivation regarding the conversion of measures to the	- Online measuring procedures for the collection of movement and noise profiles of animals in the stable, in the case of transport, and in the waiting stable; - Real-time processing of large datasets (Big DATA) from image	- Local and regional apprenticeship and in-service training facilities for animal keepers, veterinary surgeons, advisors, slaughterhouse staff, official veterinarians - EQA European qualification alliance SCE, lifelong learning

Dimensions Elements	Human/Software	Technology/Hardware	Infrastructure/Orgware
	preventive health management, risk management, and innovation management; - Recognizing intrinsic motivation vs. extrinsic motivation; - Understanding the conversion of innovation organizational models (e.g. AMOR approach, AAM model); - Understanding the implementation of QM tools, prognosis, and simulation tools (e.g. trend curves; control charts; portfolios); - Ability to audit, evaluate, and interpret management systems and standards on the basis of well-known sets of rules; - Ability to understand and control human-animal technology and environmental interactions; - Understanding and application of methods for a risk evaluation (HACCP, FMEA); - Understanding and application of methods in teamwork (Six Sigma, roundtables).	processing and sensor measurements by high computer achievements, application of Cloud programs; - Mobile data acquisition possibilities for supporting audits; - Rapid communication via the internet and social media.	concept for the agrarian and food production auditors; - Sector-specific team consulting facilities; accreditation and certification authorities (e.g. people certification).

d) Creating incentives for system innovations

During system conversions, incentives are set to offer new training and audit services for animal-keeping enterprises. Many interventions can be visually and directly recognized and measured during the process of livestock production or at the end. These interventions concern the three challenges in the production of pork. Measures including the renouncement of castration and tail docking are easily seen on the pig and thus could simply be examined by inspection personnel at the slaughterhouse.

Other measures, such as reduced antibiotic treatments or the improved amount of space and activity provided for the pigs, have to be checked and evaluated after certain uniform defaults, so that an objective evaluation is given. When different participants are involved in an audit process, it is essential to make a clear definition of test parameters, testing methods, and inspection frequencies.

Among these directly measurable criteria in the adherence to given voluntary standards or legal defaults are, for example:

- -Male pigs with testicles; without castration scars
- -Pigs with an intact curly tail; without bite wounds, necrosis, or abscesses
- -The received and used quantity of antibiotics in a certain period; recordings from both the veterinary surgeon (delivery proofs) and animal keeper (drug book)

An advantage of anatomical characteristics as target values is that they can be easily determined. This means that the pigs can be sorted and also paid for at the slaughterhouse. Moreover, this does not require high expenditure for training auditors in conformance testing for the adherence to these criteria. Monitoring activities related to defined animal health parameters, as described in the individual chapters of this work, already take place in terms of agreements in the sense of the AMOR approach. Both at the agricultural enterprise (serological monitoring of breath and diarrhea illnesses according to the definition of the health status of piglet producers and mast enterprises, MRSA and ESBL monitoring) and at the slaughterhouse (*Salmonella* monitoring, tetracycline monitoring) regular monitoring activities are coordinated and supported by a responsible network coordinator (O'Hagan 2014, Düsseldorf 2013, Schütz 2006).

Data that has already been collected is supplemented and linked with each other so that it can be processed and visualized in a group-specific manner. Investments in enterprise-wide information and communication systems are thus necessary. All participants of the chain will only carry investments if an appropriate benefit is to be expected. Ellebrecht (2008) suggests an appropriate model in which benefit portions can be computed for different system functionalities and decision situations. The current thesis has shown that animal-keeping enterprises are classified into risk categories related to their health status, the portion of smell-deviating pigs, the quantity of antibiotic use, and the presence of indicator bacteria with the view of assessing suppliers at the slaughterhouse. For each of these categories specific consulting programs and incentive systems have to be developed as a measure for a purposeful supplier promotion. Only if the involved participants know how well and/or how badly they are classified, can they modify/improve their system. Here, motivation for what a change can do plays a key role. When a farmer is keen to optimize his system, is it because he considers it to be correct or better (intrinsic motivation), or does he only perform the changes due to legal or monetary incentives (extrinsic motivation)? People who demonstrate changes in behavior due to intrinsic motivation are more content with their activity compared to extrinsically motivated people, they pursue their aims more persistently, are more pleased about reaching a target, and they can better deal with failure (Sheldon et al. 2004).

Through the studies that were implemented in this thesis it became clear that intrinsically motivated farmers are more deeply involved in the common innovation process and do more toward developing problem-solving ideas than extrinsically motivated farmers. Nevertheless, learning effects can be increased by positive and negative sanctions, premiums, or bonus-penalty systems. The visualization of KPIs in the form of trend curves and control charts improves the benchmarking between enterprises and facilitates the establishment of short-term and long-term objectives within the chain.

References

Adam, F. (2009): Ebermast oder Schmerzlinderung. In: Bayerische Landesanstalt für Landwirtschaft (Hg.): Herausforderungen für Schweinehalter. LfL-Jahrestagung. Freising, S. 29–41.

Adell, E.; Moset, V.; Zhao, Y.; Jiménez-Belenguer, A.; Cerisuelo, A.; Cambra-López, M. (2014): Comparative performance of three sampling techniques to detect airborne Salmonella species in poultry farms. In: *ANN AGR ENV MED* 21, S. 15–24.

agrarheute.com (2012): Landwirte machen regelmäßig Überstunden. Online verfügbar unter http://www.agrarheute.com/arbeitszeitkonten, zuletzt geprüft am 17.03.2015.

Alm, K.; Peltoniemi, O. A.; Koskinen, E.; Andersson, M. (2006): Porcine field fertility with two different insemination doses and the effect of sperm morphology. In: *REPROD DOMEST ANIM* 41 (3), S. 210–213.

Aluwé, M.; Millet, S.; Bekaert, K. M.; Tuyttens, F. A. M.; Vanhaecke, L.; Smet, S. de; de Brabander, D. L. (2011): Influence of breed and slaugther weight on boar taint prevalence in entire male pigs. In: *ANIMAL* 5 (8), S. 1283–1289.

Anwar, M. S.; Jaffery, G.; Rehman Bhatti, K. U.; Tayyib, M.; Bokhari, S. R. (2004): Staphylococcus aureus and MRSA nasal carriage in general population. In: *JCPSP-J COLL PHYSICI* 14, S. 661–664.

Archibald, A. (2008): Genetics of pre-disposition to boar taint. 3rd SABRE Conference: Welfare and Quality Genomics. Foulum, Denmark, 10.09.2008. Online verfügbar unter http://www.sabreeu.eu/Portals/0/SABRE%20Conference %202008/Alan_Archibald.pdf, zuletzt geprüft am 03.01.2012.

Artmann, R. (1999): Electronic identification systems: state of the art and their further development. In: *COMPUT ELECTRON AGR* 24, S. 5–26.

Aubry-Damon, H.; Grenet, K.; Sallndiaye, P.; Che, D.; Cordeiro, E.; Bougnoux, M. E.; Rigaud, E.; Le Strat, Y.; Lemainissier, V.; Aarmandlefèvre, L. (2004): Antimicrobial Resistance in Commensal Flora of Pig Farmers. In: *EMERG INFECT DIS* 5, S. 873–879.

Bau Briefe Landwirtschaft (Hg.) (2002): Praxisgerechte Mastschweinehaltung. Münster-Hiltrup: Landwirtschaftsverl (BFL-Spezial).

Bayerische Landesanstalt für Landwirtschaft (Hg.) (2006): Artgerechte, umweltfreundliche und wettbewerbsfähige Tierhaltungsverfahren. LfL Jahrestagung. Freising.

Bayerische Landesanstalt für Landwirtschaft (Hg.) (2009): Herausforderungen für Schweinehalter. LfL-Jahrestagung. Freising.

Beneke, B.; Klees, S.; Stührenberg, B.; Fetsch, A.; Kraushaar, B.; Tenhagen, B. A. (2011): Prevalence of methicillin-resistant Staphylococcus aureus in a fresh meat pork production chain. In: *J FOOD PROTECT* 74, S. 126–129.

Beuck, J. (Hg.) (2011): Tierschutz – Der „neue“ Kommunikationszugang zum Verbraucher, Aktionsprogramm Tierwohl der Westfleisch. DRV Fachtagung Vieh und Fleisch. Montabaur, 22.11.2011. Westfleisch.

Blanc, V.; Mesa, R.; Saco, M.; Lavilla, S.; Prats, G.; Miró, E.; Navarro, F.; Cortés, P.; Llagostera, M. (2006): ESBL- and plasmidic class C beta-lactamase-producing E. coli strains isolated from poultry, pig and rabbit farms. In: *VET MICROBIOL* 118, S. 299–304.

Blaschzyk, A. (1995): Modell zur Darstellung des Verlaufs einer parvovirusbedingten SMEDI-Infektion. Dissertation. Rheinische Friedrich-Wilhelms-Universität, Bonn.

Bokelmann, W. (2009): Ökonomik der Gärtnerischen Produktion, Wirtschafts- und Sozialwissenschaften des Landbaus: Wertschöpfungsketten im Gartenbau. In: vTI Landbauforschung. Sonderheft 330, S. 115–129.

Bokelmann, W.; Doernberg, A.; Schwertner, W.; Kuntosch, A.; Busse, M.; König, B.; Siebert, R.; Koschatzky, K.; Stahlecker, T. (2012): Sektorstudie zur Untersuchung des Innovationssystems der deutschen Landwirtschaft.

Bonneau, M.; Edwards, S.; Greef, K. de; Dourmad, J. Y.; Phatsara, C.; Rydhmer, L.; Edge, H.; Fabrega, E.; Gonzalez, J.; Eidnes-Sorensen, P.; Hviid, M.; Laugé, V.; Llari, E. (2011): Exploring Sustainability in Pork Production. q-porkchains, 24.03.2011.

Boogard, B. K.; Bock, B. B.; Oosting, S. J.; Wiskere, J. S. C.; van der Zjipp, A. J. (2010): Social acceptance of dairy farming: The ambivalence between the two faces of modernity. In: *J AGR AND ENVIRON ETHIC* 24 (3), S. 259–282.

Boogard, B. K.; Boekhorst, L. J. S.; Oosting, S. J.; Sørensen, J. T. (2011): Socio-cultural sustainability of pig production: Citizen perceptions in the Netherlands and Denmark. In: *LIVEST SCI* 140, S. 189–200.

Bootsma, M. C.; Wassenberg, M. W.; Trapman, P.; Bonten, M. J. (2011): The nosocomial transmission rate of animal-associated ST398 meticillin-resistant Staphylococcus aureus. In: *J R SOC INTERFACE* 8, S. 578–584.

Borell, E. von (Hg.) (2010): Immunokastration – Welche Erfahrungen sammelt die Praxis? Expertenworkshop „Verzicht auf Ferkelkastration". Berlin, 11.11.2010.

Borell, E. von (2010): Immunokastration – Welche Erfahrungen sammelt die Praxis? Expertenworkshop „Verzicht auf Ferkelkastration". Berlin, 11.11.2010.

Borell, E. von; Baumgartner, J.; Giersing, M.; Jäggin, N.; Prunier, A.; Tuyttens, F. A.; Edwards, S. A. (2008): Animal welfare implications of surgical castration and its alternatives. In: *PIGCAS DELIVERABLE D3.3*, S. 22–41.

Borrel, E. von; Bockisch, F. J.; Büscher, W.; Hoy, S.; Krieter, J.; Müller, C.; Parvizi, T.; Richter, T.; Rudovsky, A.; Sundrum, A.; van den Weghe, H. F. A. (2001): Critical control points for on-farm assessment of pig housing. In: *LIVEST PROD SCI* 72, S. 177–184.

Bornkessel, S.; Bröring, S.; Omta, S. W. F. (2014): Analysing indicators of industry convergence in four probiotics innovation value chains. In: *JOURNAL ON CHAIN AND NETWORK SCIENCE* 14 (3), S. 213–229.

Bracher-Jakob, A. (2000): Jungebermast in Forschung und Praxis. Arbeit im Auftrag der Eidgenössischen Forschungsanstalt für Nutztiere. Posieux. Online verfügbar unter http://www.agroscope.admin.ch/data/publikationen/pub_BracherJakobA_2002_19048.pdf, zuletzt geprüft am 03.01.2012.

Bracke, Stefan; Mamrot, Michel; Winzer, Petra (Hg.) (2015): Qualitätsmethoden im Diskurs zwischen Wissenschaft und Praxis. Bericht zur GQW-Jahrestagung 2015 in Wuppertal. Aachen: Shaker (17).

Brede, W.; Blaha, T. (Hg.) (2010): Tiergesundheit Schwein. Professionelles Tiergesundheitsmanagement in der modernen Schweinehaltung. Frankfurt am Main: DLG-Verl.

Brede, W.; Hoy, S. (2010): Organisationsformen zur Verbesserung der Tiergesundheit. In: W. Brede und T. Blaha (Hg.): Tiergesundheit Schwein. Professionelles Tiergesundheitsmanagement in der modernen Schweinehaltung. Frankfurt am Main: DLG-Verl, S. 54–79.

Breuer, K.; Sutcliff, M.; Mercer, J.; Rance, K.; Oconell, N.; Sneddon, I.; Edwards, S. (2005): Heritability of clinical tail-biting and its relation to performance traits. In: *LIVEST PROD SCI* 93, S. 87–94.

Brinkmann, D.; Lang, J.; Petersen, B.; Wognum, N.; Trienekens, J. H. (2011): Towards a chain coordination model for quality management strategies to strengthen the competitiveness of European pork producers. In: *JOURNAL ON CHAIN AND NETWORK SCIENCE* 11, S. 137–153.

Brinkmann, D.; Petersen, B. (2011): Nachhaltigkeit in der Wertschöpfungskette – Stufenübergreifende Management-Maßnahmen sind in der Fleischwirtschaft Mangelware. In: *FLEISCHWIRTSCHAFT* 3, S. 28–30.

Broens, E. M.; Graat, E. A.; van de Giessen, A. W.; Broekhuizen-Stins, M. J.; Jong, M. C. de (2012): Quantification of transmission of livestock-associated methicillin resistant Staphylococcus aureus in pigs. In: *VET MICROBIOL* 155, S. 381–388.

Broens, E. M.; Graat, E. A.; van der Wolf, P. J.; van de Giessen, A. W.; Jong, M. C. de (2011a): Transmission of methicillin resistant Staphylococcus aureus among pigs during transportation from farm to abattoir. In: *VET J* 189, S. 302–305.

Broens, E. M.; Graat, E. A.; van der Wolf, P. J.; van de Giessen, A. W.; van Duijkeren, E.; Wagenaar, J. A.; van Nes, A.; Mevius, D. J.; de Jong, M. C. (2011b): MRSA CC398 in the pig production chain. In: *PREV VET MED* 98, S. 182–189.

Brolund, A.; Haeggman, S.; Edquist, P. J.; Gezelius, L.; Olsson-Liljequist, B.; Wisell, K. T.; Giske, C. G. (2010): The DiversiLab system versus pulsed-field gel electrophoresis: characterisation of extended spectrum β-lactamase producing Escherichia coli and Klebsiella pneumoniae. In: *J MICROBIOL METH* 83, S. 224–230.

Bröring, S.; Leker, J.; Rühmer, S. (2006): Radical or not? Assessing innovativeness and its organisatonal implications for established firms. In: *INTERNATIONAL JOURNAL OF PRODUCT DEVELOPMENT* 3 (2), S. 152–166.

Bround, J. P.; Edwards, S. A.; Riddoch, I.; Buckner, L. J. (1998): Modification of foraging behaviour and pasture damage by dietary manipulation in outdoor sows. In: *APPL ANIM BEHAV SCI* 56, S. 173–186.

Bruns, M.; Hundt, B.; Hamer, M. (2014): Innovation management in agri-food networks and clusters. In: B. Petersen, M. Nüssel und M. Hamer: Quality and risk management in agri-food chains. Wageningen: Wageningen Academic Publishers, S. 190–200.

Bund für Umwelt- und Naturschutz (2013): Fleischatlas 2013. Daten und Fakten über Tiere als Nahrungsmittel. Online verfügbar unter http://www.bund.net/fileadmin/bundnet/publikationen/landwirtschaft/140328_bund_landwirtschaft_fleischatlas_2013.pdf.

Bundesamt für Verbraucherschutz und Lebensmittelsicherheit (2008): GERMAP. Bericht über den Antibiotikaverbrauch und die Verbreitung von Antibiotikaresistenzen in der Human- und Veterinärmedizin in Deutschland. 1. Aufl. Online verfügbar unter http://www.bvl.bund.de/SharedDocs/Downloads/08_PresseInfothek/Germap_2008.pdf?__blob=publicationFile.

Bundesamt für Verbraucherschutz und Lebensmittelsicherheit (2008): GERMAP. Bericht über den Antibiotikaverbrauch und die Verbreitung von Antibiotikaresistenzen in der Human- und Veterinärmedizin in Deutschland. Online verfügbar unter http://www.bvl.bund.de/SharedDocs/Downloads/08_PresseInfothek/Germap_2008.pdf?__blob=publicationFile.

Bundesamt für Verbraucherschutz und Lebensmittelsicherheit (2012): GERMAP. Bericht über den Antibiotikaverbrauch und die Verbreitung von Antibiotikaresistenzen in der Human- und Veterinärmedizin in Deutschland. Online verfügbar unter http://www.bvl.bund.de/SharedDocs/Downloads/05_Tierarzneimittel/germap2012.pdf?__blob=publicationFile&v=4.

Bundesinstitut für Risikobewertung (BFR) (Hg.) (2004): Internationale Fachtagung für Epidemiologie und Lebensmittelsicherheit. Berlin, 01. - 03.09.2004. Deutsche Veterinärmedizinische Gesellschaft (DVG).

Bundesinstitut für Risikobewertung (BFR) (2009): Menschen können sich über den Kontakt mit Nutztieren mit Methicillin-resistenten Staphylococcus aureus (MRSA) infizieren. Stellungnahme Nr. 014/2009 des BfR.

Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz (BMELV) (2011): Tierschutzbericht der Bundesregierung. Online verfügbar unter http://www.bmel.de/SharedDocs/Downloads/Broschueren/Tierschutzbericht_2011.pdf?__blob=publicationFile.

Bundestierärztekammer (2010): (Hg.): Leitlinien für den sorgfältigen Umgang mit antimikrobiell wirksamen Tierarzneimitteln - mit Erläuterungen der Arbeitsgruppe "Antibiotika-Leitlinien" der BTK, Arge. Vet., BfT. *Deutsches Tierärzteblatt*. Hannover: Schlütersche Verlagsgesellschaft GmbH und Co.KG.

Busch, R. J. (2006): Ethik in der Tierhaltung. In: Bayerische Landesanstalt für Landwirtschaft (Hg.): Artgerechte, umweltfreundliche und wettbewerbsfähige Tierhaltungsverfahren. LfL Jahrestagung. Freising, S. 9–16.

Busch, R. J.; Kunzmann, P. (2004): Leben mit und von Tieren. Ethisches Bewertungsmodell zur Tierhaltung in der Landwirtschaft. München: Utz.

Busch, R. J.; Kunzmann, P. (2006): Leben mit und von Tieren. Ethisches Bewertungsmodell zur Tierhaltung in der Landwirtschaft. 2. Aufl. München: Utz.

Buser, C. (2006): Wahrnehmung und Realisierung von Wertschöpfungspotentialen der Schweizer Landwirtschaft mittels organisatorisch-prozessualer Innovationen. Dissertation. ETH, Zürich, Schweiz.

Callens, B.; Persoons, D.; Maes, D.; Laanen, M.; Postma, M.; Boyen, F. Haesebrouck, F.; Butaye, P.; Catry, B.; Dewulf, J. (2012): Prophylactic and metaphylactic antimicrobial use in Belgian fattening pig herds. In: *PREV VET MED* 106, S. 53–62.

Cantón, R.; Coque, T. M. (2006): The CTX-M beta-lactamase pandemic. In: *CURR OPIN MICROBIOL* 9, S. 466–475.

Carattoli, A. (2008): Animal reservoirs for extended spectrum beta-lactamase producers. In: *CLIN MICROBIOL INFEC* 14 (1), S. 117–123.

Cavaco, L. M.; Abatih, E.; Aarestrup, F. M.; Guardabassi, L. (2008): Selection and persistence of CTX-M-producing Escherichia coli in the intestinal flora of pigs treated with amoxicillin, ceftiofur, or cefquinome. In: *ANTIMICROB AGENTS CH* 52, S. 3612–3616.

Central Veterinary Institute of Wageningen University and Research Centre (2009): MARAN 2009. Monitoring of Antimicrobial Resistance and Antibiotic Usage in Animals in the Netherlands In 2009. Online verfügbar unter http://www.wageningenur.nl/upload_mm/d/7/a/cd29a66b-aaeb-4ba2-9284-ce21ff6acc6d_MARAN2009.pdf.

Christoph, I.; Buergelt, D.; Salamon, P.; Weibele, D.; Zander, K. (2012): A Holistic Approach to Consumer Research on Expectations Regarding Animal Husbandry. Proceedings in Food System Dynamics, North America, 0, oct. 2012. Available at: http://centmapress.ilb.uni-bonn.de/ojs/index.php/proceedings/article/view/240/221. Date accessed: 31 Mar. 2015.

Colyer, R. J. (1970): Tail biting in pigs. In: *AGRICULTURE* 77, S. 215.

Cuny, C.; Köck, R.; Witte, W. (2013): Livestock associated MRSA (LA-MRSA) and its relevance for humans in Germany. In: *INT J MED MICROBIOL* 303, S. 331–337.

Cuny, C.; Nathaus, R.; Layer, F.; Strommenger, B.; Altmann, B.; Witte, W. (2009): Nasal coloinzation of humans with methicillin-resistant Staphylococcus aureus (MRSA) CC398 with and without exposure to pigs. In: *PLOS ONE* 4, e6800.

Czekala, A.; Schütz, V.; Trienekens, J. H. (2013): Lösungen für das Datenmanagement im überbetrieblichen Tiergesundheitsmanagement in der Schweineproduktion. GIL Jahrestagung 2013, 2013.

da Costa, P. M.; Loureiro, L.; Mator, A. J. F. (2013): Transfer of Multidrug-Resistant Bacteria Between Intermingled Ecological Niches: The Interface Between Humans, Animals and the Environment. In: *INT J ENVIRON RES PUBLIC HEALTH* 10, S. 278–294.

D'Allaire, S.; Friendship, R. (Hg.) (2010): Proceedings of the 21st International Pig Veterinary Society Congress: IPVS 2010. Vol. 1: oral presentations Vancouver, Canada, 18.-21.07.2010.

Day, J. (2002): The effects of prior experience of straw and the level of straw provision on the behaviour of growing pigs. In: *APP ANIM BEHAV SCI* 76, S. 189–202.

Deplano, A.; Denis, O.; Rodriguez-Villalobos, H.; de Ryck, R.; Struelens, M. J.; Hallin, M. (2011): Controlled performance evaluation of the DiversiLab repetitive-sequence-based genotyping system for typing multidrug-resistant health care-associated bacterial pathogens. In: *J CLIN MICROBIOL* 49, S. 3616–3620.

Deutscher Tierschutzbund e.V. (Hg.) (2011): Zukünftige Nutztierhaltung in Deutschland aus Sicht des Tierschutzbundes – Gibt es intensive undnachhaltige Wege? Unter Mitarbeit von T. Schröder. DRV Fachtagung Vieh und Fleisch. Montabaur, 22.11.2011.

Dirksmeyer, W. (2009): vTI Landbauforschung. Sonderheft 330.

DLG (15.01.2009): Image der Landwirtschaft deutlich verbessert. Online verfügbar unter http://presse.dlg.org/publicArticelDetail.do;jsessionid=3909BAD40BD82154B4BB17DF72CA7570?artikelId=2189&sprecheId=1&kategorieId=1&bereich=Aktuelles&type=pdf.

Düpjan, S.; Puppe, B. (2011): Wie Schweine fühlen. In: *FORSCHUNGSREPORT*, S. 35–37.

Düsseldorf, S. (2013): Concept of key performance indicators controlling consumer oriented quality and herd health management in a Bavarian pork chain. Dissertation. Rheinische Friedrich-Wilhelms-Universität, Bonn.

EFSA (2007): Scientific Opinion of the Panel on Animal Health and Welfare on a request from Commission on the risks associated with tail biting in pigs and possible means to reduce the need for tail docking considering the different housing and husbandry systems. In: *THE EFSA JOURNAL* 611, S. 1–13.

Ellebrecht, A. (2008): Nutzenbetrachtung internetbasierter Informationssysteme im einzel- und überbetrieblichen Gesundheitsmanagement. Dissertation. Rheinische Friedrich-Wilhelms-Universität, Bonn.

Ellebrecht, S. (2012): Application concept for combined preventive quality management methods in inter-enterprise health management in pork chains. Dissertation. Rheinische Friedrich-Wilhelms-Universität, Bonn.

Erlei, M.; Lehmann-Waffenschmidt, M. (Hg.) (2002): Curriculum Evolutorische Ökonomik. Lehrkonzepte zur evolutorischen Ökonomik. Marburg: Metropolis-Verl.

Escudero, E.; Vinué, L.; Teshager, T.; Torres, C.; Moreno, M. A. (2010): Resistance mechanisms and farm-level distribution of fecal Escherichia coli isolates resistant to extended-spectrum cephalosporins in pigs in Spain. In: *RES VET SCI* 88, S. 83–87.

EU (2001): EU-Richtlinie 2001/93/EG zur Änderung der Richtlinie 91/630/EWG über Mindestanforderungen für den Schutz von Schweinen.

Eurobarometer (2005): Attitudes of consumer towards the welfare of farmed animals. Eurobarometer Spezial. Online verfügbar unter http://ec.europa.eu/food/animal/welfare/euro_barometer25_en.pdf.

Eurobarometer (2007): Attitudes of EU citizens towards the welfare of farmed animals. Eurobarometer Spezial. Online verfügbar unter http://ec.europa.eu/public_opinion/archives/ebs/ebs_270_en.pdf.

Eurobarometer (2010): Europäer, Landwirtschaft und Gemeinsame Agrarpolitik. Europabarometer Spezial 336. Online verfügbar unter http://ec.europa.eu/public_opinion/archives/ebs/ebs_336_de.pdf.

Europäisches Parlament und Rat der Europäischen Union (2004): Verordnung (EG) Nr. 854/2004 des Europäischen Parlaments und des Rates vom 29. April 2004 mit besonderen Verfahrensvorschriften für die amtliche Überwachung von zum menschlichen Verzehr bestimmten Erzeugnissen tierischen Ursprungs.

European Food Safety Authority (EFSA) (2007): Scientific Opinion of the Panel on Animal Health and Welfare on a request from Commission on the risks associated with tail biting in pigs and possible means to reduce the need for tail docking considering the different housing and husbandry systems. In: *THE EFSA JOURNAL* 611, S. 1–13.

European Food Safety Authority (EFSA) (2008): Foodborne antimicrobial resistance as a biological hazard - Scientific Opinion of the Panel on Biological Hazards. In: *THE EFSA JOURNAL* 765, S. 1–87.

Evans, A.; Miele, M. (2008): Consumers`views about farm animal welfare. Part II: European comparative report based on focus group research. Welfare Quality Report No. 5. Cardiff School of City and Regional Planning. Cardiff.

Feller, W. (1948): On the Kolmogorov-Smirnov Limit Theorems for Empirical Distributions. In: *ANN MATH STAT*, S. 177–189.

Fitz-Gibbon, Carol Taylor (1990): Performance indicators. Clevedon: Multilingual Matters (BERA dialogues, 2).

Font I Furnols, M.; Gispert, M.; Diestre, A.; Oliver, M. A. (2003): Acceptability of boar meat by consumers depending on their age, gender, culinary habits, and sensitivity and appreciation of androstenone odour. In: *MEAT SCI* 64, S. 433–440.

Fredriksen, B.; Lium, B. M.; Marka, C. H.; Mosveen, B.; Nafstad, O. (2008): Entire male pigs in farrow-to-finish pens – effects on animal welfare. In: *APPL ANIM BEHAV SCI* 110, S. 258–268.

Freeman, C. (2002): Continental, national and sub-national innovation systems – complementarity and economic growth. In: *RES POLICY* 31, S. 191–211.

Freitag, M. (2014): Schwanzbeißen bei Schweinen – ein altes Problem neu im Fokus. In: *GFS AKTUELL* 11, S. 48–51.

Freitag, M.; Böhmer, K.; Jaeger, F. (2012): Kaudophagie beim Schwein – ein multifaktorelles Problem. In: *NUTZTIERPRAXIS AKTUELL*, S. 104–405.

Frieden, L.; Looft, C.; Tholen, E. (2011): Breeding for reduced boar taint. In: *LOHMANN INFORMATION* 46, S. 21.

Friese, A.; Schulz, J.; Hoehle, L.; Fetsch, A.; Tenhagen, B. A.; Hartung, J.; Roesler, U. (2012): Occurrence of MRSA in air and housing environment of pig barns. In: *VET MICROBIOL* 158, S. 129–135.

Friese, A.; Schulz, J.; Laube, H.; Salviati, C.; Hartung, J.; Roesler, U. (2013): Faecal occurrence and emissions of livestock-associated methicillin-resistant Staphylococcus aureus (laMRSA) and ESbl/AmpC-producing E. coli from animal farms in Germany. In: *BERL MUNCH TIERARZTL* 126, S. 175–180.

Gantner, U. (2011): Die Welt neu entwerfen – Systeminnovation. In: *AGAR FORSCHUNG SCHWEIZ* 2, S. 59.

Gerybadze, A.; Meyer-Krahmer, F.; Reger, G. (Hg.) (1997): Globales Management von Forschung und Innovation. Stuttgart: Schäffer-Poeschel.

Geser, N.; Stephan, R.; Hächler, H. (2012a): Occurrence and characteristics of extended-spectrum β-lactamase (ESBL) producing Enterobacteriaceae in food producing animals, minced meat and raw milk. In: *BMC VET RES* 8, S. 21.

Geser, N.; Stephan, R.; Korczak, B. M.; Beutin, L.; Hächler, H. (2012b): Molecular identification of extended-spectrum-β-lactamase genes from Enterobacteriaceae isolated from healthy human carriers in Switzerland. In: *ANTIMICROB AGENTS CH* 56, S. 1609–1612.

Geser, N.; Stephan, R.; Kuhnert, P.; Zbinden, R.; Kaeppeli, U.; Cernela, N.; Haechler, H. (2011): Fecal carriage of extended-spectrum β-lactamase-producing Enterobacteriaceae in swine and cattle at slaughter in Switzerland. In: *J FOOD PROTECT* 74, S. 446–449.

Gibbs, S. G.; Green, C. F.; Tarwater, P. M.; Scarpino, P. V. (2004): Airborne antibiotic resistant and nonresistant bacteria and fungi recovered from two swine herd confined animal feeding operations. In: *J OCCUP ENVIRON HYG* 1, S. 699–706.

Gilchrist, M. J.; Greko, C.; Wallinga, D. B.; Beran, G. W.; Riley, D. G.; Thorne, P. S. (2007): The potential role of concentrated animal feeding operations in infectious disease epidemics and antibiotic resistance. In: *ENVIRON HEALTH PERSP* 115, S. 313–316.

Gonçalves, A.; Torres, C.; Silva, N.; Carneiro, C.; Radhouani, H.; Coelho, C.; Araújo, C.; Rodrigues, J.; Vinué, L.; Somalo, S.; Poeta, P.; Igrejas, G. (2010): Genetic characterization of extended-spectrum beta-lactamases in Escherichia coli isolates of pigs from a Portuguese intensive swine farm. In: *FOODBORNE PATHOG DIS* 7, S. 1569–1573.

Götz, K. U.; Littmann, E.; Wittmann, W.; Dodenhoff, J. (2009): Impfung gegen Ebergeruch oder züchterische Maßnahmen. In: Bayerische Landesanstalt für Landwirtschaft (Hg.): Herausforderungen für Schweinehalter. LfL-Jahrestagung. Freising, S. 43–51.

Graveland, H.; Duim, B.; van Duijkeren, E.; Heederik, D.; Wagenaar, J. A. (2011a): Livestock-associated methicillin-resistant Staphylococcus aureus in animals and humans. In: *INT J MED MICROBIOL* 301, S. 630–634.

Graveland, H.; Wagenaar, J. A.; Bergs, K.; Heesterbeek, H.; Heederik, D. (2011b): Persistence of livestock associated MRSA CC398 in humans is dependent on intensity of animal contact. In: *PLOS ONE* 6, e16830.

Green, C. F.; Gibbs, S. G.; Tarwater, P. M.; Mota, L. C.; Scarpino, P. V. (2006): Bacterial plume emanating from the air surrounding swine confinement operations. In: *J OCCUP ENVIRON HYG* 3, S. 9–15.

Grindflek, E. (2008): Genetics and genomics of boar taint – ongoing research in Norway. 3rd SABRE Conference: Welfare and Quality Genomics. Foulum, Denmark, 10.09.2008. Online verfügbar unter http://www.sabre-eu.eu/Portals/0/SABRE%20Conference%202008/Eli_Grindflek.pdf, zuletzt geprüft am 10.11.2011.

Grindflek, E.; Meuwissen, T. H. E.; Aasmundstad, T.; Hamland, H.; Hansen, M. H. S.; Nome T.; Kent, M.; Torjesen, P.; Lien, S. (2010): Revealing genetic relationships between compounds affecting boar taint and reproduction in pigs. In: *J ANIM SCI* 89, S. 680–692.

Grohs, P.; Tillecovidin, B.; Caumont-Prim, A.; Carbonelle, E.; Day, N.; Podglajen, I.; Gutmann, L. (2013): Comparison of five media for detection of extended-spectrum Beta-lactamase by use of the wasp instrument for automated specimen processing. In: *J CLIN MICROBIOL* 51, S. 2713–2716.

Grupp, P. W. (1994): The measurement of technical performance of innovations by technometrics and its impat on established technology indicators. In: *RES POLICY* 23 (2), S. 175–193.

Gymnich, S. (2001): Haptoglobin als Screeningparameter im Gesundheitsmanagement von Ferkelaufzuchtbetrieben. Dissertation. Rheinische Friedrich-Wilhelms-Universität, Bonn.

Hakkinen, T.; Valros, A.; Ahlstrom, S.; Salomiemi, H. (2002): The prevalence of tail-biting in integrated and finishing units and the interaction between tail-biting and housing factors in quality-classified swine units. In: *SUOMEN ELAINLAAKARILEHTI* 108, S. 141–147.

Hammerum, A. M.; Heuer, O. E.; Lester, C. H.; Agersø, Y.; Seyfarth, A. M.; Emborg, H. D.; Frimodt-Møller, N.; Monnet, D. L. (2007): Comment on: withdrawal of growth-promoting antibiotics in Europe and its effects in relation to human health. In: *INT J ANTIMICROB AG* 30, S. 466–468.

Hammerum, A. M.; Larsen, J.; Andersen, V. D.; Lester, C. H.; Skovgaard Skytte, T. S.; Hansen, F.; Olsen, S. S.; Mordhorst, H.; Skov, R. L.; Aarestrup, F. M.; Agersø, Y. (2014): Characterization of extended-spectrum β-lactamase (ESBL)-producing Escherichia coli obtained from Danish pigs, pig farmers and their families from farms with high or no consumption of third- or fourth-generation cephalosporins. In: *J ANTIMICROB CHEMOTH* 69.

Hansen, K. H.; Damborg, P.; Andreasen, M.; Nielsen, S. S. Guardabassi L. (2013): Carriage and fecal counts of cefotaxime M-producing Escherichia coli in pigs: a longitudinal study. In: *APPL ENVIRON MICROB* 79, S. 794–798.

Hansen, L. L.; Mejer, H.; Thamsborg, S. M.; Byrne, D. V.; Roepstorff, A.; Karlsson, A. H.; Hansen-Moller, J.; Jensen, M. T.; Tuomola, M. (2006): Influence of chicory roots (Cichorium intybus L) on boar taint in entire male and female pigs. In: *ANIM SCI* 82, S. 359–368.

Harlizius, B.; Duijvesteijn, N.; Knol, E. F. (Hg.) (2009): High-density genome association study for androstenone in a terminal sire line. Book of abstract of the 60th Annual meeting of the EAAP. Barcelona, Spanien.

Harmsen, D.; Claus, H.; Witte, W.; Rothgänger, J.; Turnwald, D.; Vogel, U. (2003): Typing of methicillin-resistant Staphylococcus aureus in a university hospital setting by using novel software for spa repeat determination and database management. In: *J CLIN MICROBIOL* 41, S. 5442–5448.

Harper, G.; Henson, S. (2001): Consumer Concerns about Animal Welfare and the Impact on Food Choice. Final Report. EU FAIR Project CT98-3678. The University of Reading. Reading.

Harris, Delbert Linn (2000): Multi-site pig production. Ames: Iowa State University Press.

Harrison, E. M.; Paterson, G. K.; Holden, M. T.; Larsen, J.; Stegger, M.; Larsen, A. R. Petersen, A.; Skov, R. L.; Christensen, J. M.; Bak Zeuthen, A.; Heltberg, O.; Harris, S. R.; Zadoks, R. N.; Parkhill, J.; Peacock, S. J.; Holmes, M. A. (2013): Whole genome sequencing identifies zoonotic transmission of MRSA isolates with the novel mecA homologue mecC. In: *EMBO MOL MED* 5, S. 509–515.

Hauschildt, J. (1997): Innovationsmanagement. 2. Aufl. München: Vahlen.

Hawkey, P. M.; Jones, A. M. (2009): The changing epidemiology of resistance. In: *J ANTIMICROB CHEMOTH* 64 (1), S. i3-10.

Haxsen, G.; Blaha, T.; Grosse Austing, S. (2004): Kosten-Nutzen-Analysen von Maßnahmen im Bereich der Tiergesundheit. In: Bundesinstitut für Risikobewertung (BFR) (Hg.): Internationale Fachtagung für Epidemiologie und Lebensmittelsicherheit. Berlin, 01. - 03.09.2004. Deutsche Veterinärmedizinische Gesellschaft (DVG).

Heid, A.; Hamm, U. (Hg.) (2011): Alternativen zur betäubungslosen Ferkelkastration: Verbraucherakzeptanz. 11. Wissenschaftstagung Ökologischer Landbau. Gießen, 15.-18. März 2011. Justus-Liebig-Universität Gießen. Berlin: Dr. Köster.

Hessel, E. F.; Wulbers-Mindermann, M.; Berg, C.; van den Weghe, H. F. A.; Algers, B. (2006): Influence of increased feeding frequency on behavior and integument lesions in growing-finishing restricted-fed pigs. In: *J ANIM SCI* 84, S. 1526–1534.

Hiramatsu, K.; Okuma, K.; Ma, X. X.; Yamamoto, M.; Hori, S.; Kapi, M. (2002): New trends in Staphylococcus aureus infections: glycopeptide resistance in hospital and methicillin resistance in the community. In: *CURR OPIN INFECT DIS* 15, S. 407–413.

Hoeck, J.; Büscher, W.: Temperature-dependent water intake behavior of weaned piglets. Proceedings of the 6th European Conference on Precision Livestock Farming. Leuven (Belgium), S. 724–730.

Homburg, C. (1995): Kundennähe von Industriegüterunternehmen. Konzeption - Erfolgsauswirkungen - Determinanten.

Homburg, C. (1995): Kundennähe von Industriegüterunternehmen. Konzeption - Erfolgsauswirkungen - Determinanten. Wiesbaden: Gabler (Neue betriebswirtschaftliche Forschung, 147).

Horton, R. A.; Randall, L. P.; Snary, E. L.; Cockrem, H.; Lotz, S.; Wearing, H.; Duncan, D.; Rabie, A.; McLaren, I.; Watson, E.; La Ragione, R. M.; Coldham, N. G. (2011): Fecal carriage and shedding density of CTX-M extended-spectrum {beta}-lactamase-producing escherichia coli in cattle, chickens, and pigs: implications for environmental contamination and food production. In: *APPL ENVIRON MICROB* 77, S. 3715–3719.

Hörügel, K.: Tiergesundheitsmanagement in der Schweinehaltung. Schriftenreihe der Sächsischen Landesanstalt für Landwirtschaft, Heft 2, 7. Jahrgang. Dresden: Sächsisches Druck- und Verlagshaus.

Hu, Y. Y.; Cai, J. C.; Zhou, H. W.; Chi, D.; Zhang, X. F.; Chen, W. L.; Zhang, R.; Chen, G. X. (2013): Molecular typing of CTX-M-producing escherichia coli isolates from environmental water, swine feces, specimens from healthy humans, and human patients. In: *APPL ENVIRON MICROB* 79, S. 5988–5996.

Huber-Eicher, B. (2008): Alternative Methoden zur konventionellen Ferkelkastration ohne Schmerzausschaltung. Umfrageergebnisse der repräsentativen Imagestudie Schweizerfleisch 2006. Bern. Online verfügbar unter http://www.shl.bfh.ch/fileadmin/docs/Forschung/KompetenzenTeams/Nutztier-UmweltInteraktion/ProSchwein/Synthesebericht/B13_Umfrageergebnisse_der_repr_sentativen_Imagestudie_20080331.pdf, zuletzt geprüft am 10.11.2011.

Huber-Eicher, B.; Spring, P. (2008): Attitudes of Swiss consumers towards meat from entire or immunocastrated boars: A representative survey. In: *RES VET SCI* 85 (3), S. 625–627.

Huletsky, A.; Lebel, P.; Picard, F. J.; Bernier, M.; Gagnon, M.; Boucher, N.; Bergeron, M. G. (2005): Identification of methicillin-resistant Staphylococcus aureus carriage in less than 1 hour during a hospital surveillance program. In: *CLIN INFECT DIS* 40, S. 976–981.

Hunter, E. J.; Jones, T. A.; Guise, H. J.; Penny, R. H. C.; Hoste, S. (2001): The Relationship between Tail Biting in Pigs, Docking Procedure and Other Management Practices. In: *VET J* 161, S. 72–79.

Hurd, H. S.; Gailey, J. K.; McKean, J. D.; Rostagno, M. H. (2001): Rapid infection in market-weight swine following exposure to a Salmonella typhimurium-contaminated environment. In: *AM J VET RES* 62, S. 1194–1197.

Hurd, H. S.; McKean, J. D.; Griffith, R. W.; Wesley, I. V.; Rostagno, M. H. (2002): Salmonella enterica infections in market swine with and without transport and holding. In: *APPL ENVIRON MICROB* 68, S. 2376–2381.

Institut für Agrartechnik der Universität Hohenheim (Hg.) (2001): Bau, Technik und Umwelt in der landwirtschaftlichen Nutztierhaltung. Beiträge zur 5. Internationalen Tagung 2001. Stuttgart-Hohenheim, 06.-07.03.2001.

ISO 11784-2:2010-06: Radio frequency identification of animals – Code structure.

ISO 11785-2008-12: Radio frequency identification of animals – Technical concept.

Jaeger, F. (2013): The project intact curly tails in pigs-are we just before a breakthrough? In: *TIERAERZTL UMSCHAU* 68, S. 3–11.

Jakobsen, L.; Kurbasic, A.; Skjøt-Rasmussen, L.; Ejrnaes, K.; Porsbo, L. J.; Pedersen, K.; Jensen, L. B.; Emborg, H. D.; Agersø, Y.; Olsen, K. E.; Aarestrup, F. M.; Frimodt-Møller, N.; Hammerum, A. M. (2010): Escherichia coli isolates from broiler chicken meat, broiler chickens, pork, and pigs share phylogroups and antimicrobial resistance with community-dwelling humans and patients with urinary tract infection. In: *FOODBORNE PATHOG DIS* 7, S. 537–547.

Jankevicius, M. (2004): The effect of ACTH on pigs? Attraction to salt or blood-flavored tail-models. In: *APPL ANIM BEHAV SCI* 87, S. 55–68.

Jensen, T.; Busch, M. E.; Riis, A. L.; Maribo, H.; Vernersen, A. (2004): Halebid: Manual om forebyggelse og handtering. Landsudvalget for Svin. In: *DANSKE SLAGTERIER*.

Kagfreiland (2007): Die Ebermast funktioniert! Zwischenbericht 2007 über das kagfreiland-Projekt „Eber statt Kastration". Schweiz. Online verfügbar unter http://www.kagfreiland.ch/media/c_Tierprojekte/01_Eber/04_Infos/b_mitte/2007_Eberbericht.pdf, zuletzt geprüft am 18.11.2011.

Kamiske, G. F.; Brauer, J. P. (2008): Qualitätsmanagement von A bis Z. München: Carl Hanser Verlag.

Kastrup, G. N. (2011): Untersuchung zum Vorkommen Meticillin–resistenter Staphylococcus aureus entlang der Schlachtlinie und im Zerlegebereich bei der Gewinnung roher Fleischwaren von Schweinen. Dissertation. Tierärztliche Hochschule, Hannover.

Kayser, M.; Schlieker, K.; Spiller, A. (2012): Die Wahrnehmung des Begriffs „Massentierhaltung" aus Sicht der Gesellschaft. In: *BERICHTE ÜBER LANDWIRTSCHAFT* 90 (3), S. 417–428.

Khanna, T.; Friendship, R.; Dewey, C.; Weese, J. S. (2008): Methicillin resistant Staphylococcus aureus colonization in pigs and pig farmers. In: *VET MICROBIOL* 128, S. 298–303.

Klauke, T. N. (2013): Risk based approach towards more sustainability in European pig production. Dissertation. Rheinische Friedrich-Wilhelms-Universität, Bonn.

Klauke, T. N.; Brinkmann, D. (2009): Kosteneffizienz durch Six Sigma Prozessoptimierung – Chancen für die Fleischproduktion. In: *FLEISCHWIRTSCHAFT* 8, S. 16–22.

Klauke, T. N.; Houwers, H. W. J.; Cinar, M. U.; Schellander, K.; Petersen, B.; Bonneau, M. (2013): Evaluation of the quality of health management in contrasted pig husbandry systems in Europe. Dissertation. Rheinische Friedrich-Wilhelms-Universität, Bonn.

Kluivers-Poodt, M.; Hopster, H. (2007): Animal Science Group Report 85 „Castration under anaesthesia and/or analgesia in commercial pig production". Wageningen: Animal Sciences Group.

Knoop, S. (2010): Literaturauswertung zum Thema Schwanzbeißen / Schwänze kupieren. Hg. v. Bildungs- und Wissenszentrum Boxberg. Landesanstalt für Schweinezucht - LSZ.

Knura-Deszczka, S. (2000): Bewertung von Haptoglobin als Parameter zur Einschätzung des Gesundheitsstatus von Mastschweinen. Dissertation. University of Veterinary Medicine, Hannover.

Köck, R.; Ballhausen, B.; Bischoff, M.; Cuny, C.; Eckmanns, T.; Fetsch, A. Harmsen, D.; Goerge, T.; Oberheitmann, B.; Schwarz, S.; Selhorst, T.; Tenhagen, B. A.; Walther, B.; Witte, W.; Ziebuhr, W.; Becker, K. (2014): The impact of zoonotic MRSA colonization and infection in Germany. MRSA als Erreger von Zoonosen in Deutschland. In: *BERL MUNCH TIERARZTL* 127, S. 384–398.

Köck, R.; Brase, K.; Harlizius, J.; Koeksal, M.; Nienhoff, H.; Schulte-Wuelwer, J.; Friedrich, A. W. (2013): MRSA and ESBL-producing enterobacteria in German pig holdings. In: *INT J OF MED MICROBIOL* 303, S. 108.

Köck, R.; Harlizius, J.; Bressan, N.; Laerberg, R.; Wieler, L. H.; Witte, W.; Deurenberg, R. H.; Voss, A.; Becker, K.; Friedrich, A. W. (2009): Prevalence and molecular characteristics of methicillin-resistant Staphylococcus aureus (MRSA) among pigs on German farms and import of livestock-related MRSA into hospitals. In: *EUR J CLIN MICROBIOL* 28, S. 1375–1382.

Köck, R.; Mellmann, A.; Schaumburg, F.; Friedrich, A. W.; Kipp, F.; Becker, K. (2011): The epidemiology of methicillin-resistant Staphylococcus aureus (MRSA) in Germany. In: *DTSCH ARZTEBL INT* 108 (45), S. 761–770.

Kohler, I.; Moens, Y.; Busato, A.; Blum, J.; Schatzmann, U. (1988): Inhalation anaesthesia for the castration of piglets: CO2 compared to halothane. In: *ZBL VET MED A* 45 (10), S. 625–633.

Kommission (2008): Verordnung (EG) Nr. 889/2008 der Kommission vom 5. September 2008 mit Durchfüh¬rungsvorschriften zur Verordnung (EG) Nr. 834/2007 des Rates über die ökologische/ biologische Produktion und die Kennzeichnung von ökologischen/biologischen Erzeugnissen hinsichtlich der ökologischen/biologischen Produktion, Kennzeichnung und Kontrolle.

Koopmans, S. J.; Guzik, A. C.; van der Meulen, J.; Dekker, R.; Kogut, J.; Kerr, B. J.; Southern, L. L. (2006): Effects of supplemental L-tryptophan on serotonin, cortisol, intestinal integrity, and behavior in weanling piglets. In: *J ANIM SCI* 84, S. 963–971.

Kreyenschmidt, J. (2003): Modellierung des Frischeverlustes von Fleisch sowie des Entfärbeprozesses von Temperatur-Zeit-Integratoren zur Festlegung von Anforderungsprofilen für die produktbegleitende Temperaturüberwachung. Dissertation. Rheinische Friedrich-Wilhelms-Universität, Bonn.

Krieter, J. (2010): Chancen und Risiken der Ebermast. In: SCHRIFTENREIHE DER AGRAR-UND ERNÄHRUNGSWISSENSCHAFTLICHEN FAKULTÄT DER UNIVERSITÄT KIEL 116, S. 105–110.

Kritas, S. K.; Morrison, R. B. (2007): Relationships between tail biting in pigs and disease lesions and condemnations at slaughter. In: *VET REC* 160, S. 149–152.

Krommweh, M. S.; Rösmann, P.; Büscher, W. (2014): Investigation of heating and cooling potential of a modular housing system for fattening pigs with integrated geothermal heat exchanger. In: *BIOSYST ENG* 121, S. 118–129.

KTBL (2008): Datensammlung Betriebsplanung Landwirtschaft 2008/2009. 21. Aufl. Darmstadt: KTBL.

Künneken, J. (1991): Simulation der Tier - Bakterium - Umwelt - Interaktion im Biotop "Abferkelstall". Dissertation. Rheinische Friedrich-Wilhelms-Universität, Bonn.

Landwirtschaftskammer Nordrhein-Westfalen: Betriebszweigauswertung Ferkelerzeugung in Nordrhein-Westfalen Wj. 2009/2010. Unveröffentlichtes Dokument.

Landwirtschaftskammer Nordrhein-Westfalen: Betriebszweigauswertung Schweinemast in Nordrhein-Westfalen Wj. 2009/2010. Unveröffentlichtes Dokument.

Lang, J.; Petersen, B. (2012b): - improving inspection strategies in agri-food supply chains. 22nd Annual IFAMA World Forum and Symposium. "The Road to 2050: The China Factor". Shanghai, China, 2012b.

Lang, J.; Petersen, B. (2012): AMOR - Mutuale Prüfstrategien in komplexen Kunden- und Lieferantenbeziehungen der Agrar- und Ernährungswirtschaft. In: R. Woll und M. Uhlemann (Hg.): Vielfalt Qualität - Tendenzen im Qualitätsmanagement. Bericht zur GQW-Jahrestagung 2012 in Cottbus. Aachen: Shaker, S. 45–60.

Lassen, J.; Sandøe, P.; Forkman, B. (2006): Happy pigs are dirty! – Conflicting perspectives on animal welfare. In: *LIVEST SCI* 103 (3), S. 221–230.

Lassok, B.; Tenhagen, B. A. (2013): From pig to pork: methicillin-resistant Staphylococcus aureus in the pork production chain. In: *J FOOD PROTECT* 76, S. 1095–1108.

Leelaporn, A.; Paulsen, I. T.; Tennent, J. M.; Littlejohn, T. G.; Skurray, R. A. (1994): Multidrug resistance to antiseptics and disinfectants in coagulase-negative staphylococci. In: *J MED MICROBIOL* 40, S. 214–220.

Leverstein-van Hall, M. A.; Dierikx, C. M.; Cohen Stuart, J.; Voets, G. M.; van den Munckhof, M. P.; van Essen-Zandbergen, A.; Platteel, T.; Fluit, A. C.; van Sande-Bruinsma, N. de; Scharinga, J.; Bonten, M. J. M.; Mevius, D. J. (2011): Dutch patients, retail chicken meat and poultry share the same ESBL genes, plasmids and strains. In: *CLIN MICROBIOL INFEC* 17, S. 873–880.

Li, Y. Z.; Kerr, B. J.; Kidd, M. T.; Gonyou, H. W. (2006): Use of supplementary tryptophan to modify the behavior of pigs. In: *J ANIM SCI* 84, S. 212–220.

Lieber, K.; Moormann, J. (2004): Six Sigma: Neue Chancen zur Produktivitätssteigerung? In: *DIE BANK* 01/04, S. 28–33.

Link, M. (2008): Alternativen zur betäubungslosen Ferkelkastration. In: G. Rahmann und U. Schumacher (Hg.): Praxis trifft Forschung. Neues aus der Ökologischen Tierhaltung. Ausgewählte Beiträge der Internationalen Tagungen zur Ökologischen Schaf/Ziegen-, Schweine-, Milchkuh- und Geflügelhaltung 2007/2008. Braunschweig.

Littlejohn, T. G.; Paulsen, I. T.; Gillespie, M. T.; Tennent, J. M.; Midgley, M.; Jones, I. G.; Purewal, A. S.; Skurray, R. A. (1992): Substrate specificity and energetics of antiseptic and disinfectant resistance in Staphylococcus aureus. In: *FEMS MICROBIOL LETT* 74, S. 259–265.

Liu, B. T.; Yang, Q. E.; Li, L.; Sun, J.; Liao, X. P.; Fang, L. X.; Yang, S. S.; Deng, H.; Liu, Y. H. (2013): Dissemination and characterization of plasmids carrying oqxAB-bla CTX-M genes in Escherichia coli isolates from food-producing animals. In: *PLOS ONE* 8, e73947.

Madey, D. P. (2014): Evaluation of a software–based intervention tool for the reduction of tail biting in German fattening pigs. Dissertation. University of Veterinary Medicine, Hannover.

Marggraf, R.; Streb, S. (1997): Ökonomische Bewertung der natürlichen Umwelt. Theorie, politische Bedeutung, ethische Diskussion. Heidelberg: Spektrum Akad. Verl.

Marshall, B. M.; Levy, S. B. (2011): Food animals and antimicrobials: impacts on human health. In: *CLIN MICROBIOL REV* 24, S. 718–733.

Mathew, A. G.; Cissell, R.; Liamthong, S. (2007): Antibiotic resistance in bacteria associated with food animals: a United States perspective of livestock production. In: *FOODBORNE PATHOG DIS* 4, S. 115–133.

Matthews, K. R.; Homer, D. B.; Punter, P.; Beague, M. P.; Gispert, M.; Kempster, A. J.; Agerhem, H.; Claudi-Magnussen, C.; Fischer, K.; Siret, F.; Leask, H.; Font I Furnols, M.; Bonneau, M. (2000): An international study on the importance of androstenone and skatole for boar taint: III. Consumer survey in seven European countries. In: *MEAT SCIENCE* 54 (3), S. 271–283.

McIntyre, B. D.; Herre, H. R.; Wakhungu, J.; Watson, R. T. (2009): International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) Agriculture at a Crossroads: Global Report. Washington, D.C.: Island Press, 2009.

Meemken, D.; Cuny, C.; Witte, W.; Eichler, U.; Staudt, R.; Blaha, T. (2008): Occurrence of MRSA in pigs and in humans involved in pig production--preliminary results of a study in the northwest of Germany. In: *DTSCH TIERARZTL WOCH* 115, S. 132–139.

Meinders, L.; Schulze-Geisthövel, S.; Eynck, H. J.; Jaeger, F.; Petersen, B. (Hg.): Visualisierung von Key Performance Indicators bei der Lieferantenbewertung in der Fleischwirtschaft. Band 17/2015: Shaker Verlag (Band 17/2015).

Meinders, L.; Schulze-Geisthövel, S.; Eynck, H. J.; Jaeger, F.; Petersen, B. (2015): Visualisierung von Key Performance Indicators bei der Lieferantenbewertung in der Fleischwirtschaft. In: Stefan Bracke, Michel Mamrot und Petra Winzer (Hg.): Qualitätsmethoden im Diskurs zwischen Wissenschaft und Praxis. Bericht zur GQW-Jahrestagung 2015 in Wuppertal. Aachen: Shaker (17), S. 125–144.

Mester, M.; Seelhorst, S. (2006): Kannibalismus übers Futter vorbeugen. In: *DLZ-AGRARMAGAZIN 3, PRIMUS SCHWEIN*, S. 20–23.

Millenium Ecosystem Assessment (MA (2005): Ecosystems And Human Well-Being. Washington, D.C.: Island Press.

MLC (2004): Finishing pigs. Systems Research: Production Trial 1. In: *BPEX, MILTON KEYNES*.

MLC (2005): Finishing pigs. Systems Research: Production Trials 2. In: *BPEX, MILTON KEYNES*.

Moinard, C. (2003): A case control study of on-farm risk factors for tail biting in pigs. In: *APPL ANIM BEHAV SCI* 81, S. 333–355.

Monaco, M.; Pedroni, P.; Sanchini, A.; Bonomini, A.; Indelicato, A.; Pantosti, A. (2013): Livestock-associated methicillin-resistant Staphylococcus aureus responsible for human colonization and infection in an area of Italy with high density of pig farming. In: *BMC INFECT DIS* 13, S. 258.

Moodley, A.; Guardabassi, L. (2009): Transmission of IncN plasmids carrying blaCTX-M-1 between commensal Escherichia coli in pigs and farm workers. In: *ANTIMICROB AGENTS CH* 53, S. 1709–1711.

Muehlbauer, I.; Otten, W.; Luepping, W.; Palzer, A.; Zoels, S.; Elicker, S.; Ritzmann, M.; Heinritzi, K. (2009): Investigation about CO2 gas anaesthesia as an alternative option for piglet castration without anaesthesia (in German). In: *PRAKT TIERARZT* 90, S. 460–464.

Murarta, H.; Shimada, N.; Yoshioka, M. (2004): Current research on acute phase proteins in veterinary diagnosis: an overview. In: *VET J* 168, S. 28–40.

Naseer, U.; Sundsfjord, A. (2011): The CTX-M conundrum: dissemination of plasmids and Escherichia coli clones. In: *MICROB DRUG RESIST* 17, S. 83–97.

Nationale Forschungsplattform für Zoonosen (Hg.) (2013b): National Symposium on Zoonoses Research 2013. Best poster award.

Nedbalcova, K.; Nechvatalova, K.; Pokludova, L.; Bures, J.; Kucerova, Z.; Koutecka, L.; Hera, A. (2014): Resistance to selected beta-lactam antibiotics. In: *VET MICROBIOL* 171, S. 328–336.

Neeling, A. J. de; van den Broek, M. J.; Spalburg, E. C.; van Santen-Verheuvel, M. G.; Dam-Deisz, W. D. C.; Boshuizen, H. C.; van de Giessen, A. W.; van Duijkeren, E.; Huijsdens, X. W. (2007): High prevalence of methicillin resistant Staphylococcus aureus in pigs. In: *VET MICROBIOL* 122, S. 366–372.

Nübel, U.; Dordel, J.; Kurt, K.; Strommenger, B.; Westh, H.; Shukla, S. K.; .; Žemličková, H.; Leblois, R.; Wirth, T.; Jombart, T.; Balloux, F.; Witte, W. (2010): A timescale for evolution, population expansion, and spatial spread of an emerging clone of methicillin-resistant Staphylococcus aureus. In: *PLOS PATHOG* 6, e1000855.

O'Hagan, J. (2014): Strategies for risk oriented inspections between customers and suppliers in agri-food supply chains. Dissertation. Rheinische Friedrich-Wilhelms-Universität, Bonn.

Parlamentarischer Rat (1949): Grundgesetz für die Bundesrepublik Deutschland.

Paul, E. S.; Moinard, C.; Green, L. E.; Mendl, M. (2007): Farmers' attitudes to methods for controlling tail biting in pigs. In: *VET REC* 160, S. 803–805.

Petersen, B. (2013): ‚Health-proofed Europe' – eine Vision zur Harmonisierung und Standardisierung in der Schweinefleischerzeugung. Frühjahrssymposium AfT. Moderne Schweinehaltung und Tiergesundheit – ein Widerspruch? Montabaur, 2013.

Petersen, B.; Nüssel, M.; Hamer, M. (2014): Quality and risk management in agri-food chains. Wageningen: Wageningen Academic Publishers.

Pitout, J. D.; Sanders, C. C.; Sanders, W. E., JR. (1997): Antimicrobial resistance with focus on beta-lactam resistance in gram-negative bacilli. In: *AM J MED* 103, S. 51–59.

Prange, H. (Hg.) (2004): Gesundheitsmanagement Schweinehaltung. Stuttgart: Ulmer.

Price, L. B.; Stegger, M.; Hasman, H.; Aziz, M.; Larsen, J.; Andersen, P. S.; Pearson, T.; Waters, A. E.; Foster, J. T.; Schupp, J.; Gillece, J.; Driebe, E.; Liu, C. M.; Springer, B.; Zdovc, I.; Battisti, A.; Franco, A.; Zmudzki, J.; Schwarz, S.; Butaye, P.; Jouy, E.; Pomba, C.; Concepción Porrero, M.; Ruimy, R.; Smith, T. C.; Robinson, D. A.; Weese, J. S.; Arriola, C. S.; Yu, F.; Laurent, F.; Keim, P.; Skov, R.; Aarestrup, F. M. (2012): Staphylococcus aureus CC398: host adaptation and emergence of methicillin resistance in livestock. In: *MBIO* 3, S. e00305-11.

Pütz, S. (2014): Entwicklung und Validierung von praxistauglichen Maßnahmen zum Verzicht des routinemäßigen Schwänzekupierens beim Schwein in der konventionellen Mast. Dissertation. Georg-August-Universität, Göttingen.

Pütz, S.; Jaeger, F.; Wieland, C.; Rohn, K.; Kaes, S. (2011): Schwanzbeißen beim Schwein überwinden. Ein Beitrag zur ganzheitlichen, ursachenorientierten Lösung des Problems. In: *TIERAERZTL UMSCHAU* 66, S. 349–354.

Raab, V. (2011): Assessment of novel temperature monitoring systems for improving cold chain management in meat supply chains. Dissertation. Rheinische Friedrich-Wilhelms-Universität, Bonn.

Rahmann, G.; Schumacher, U. (Hg.) (2008): Praxis trifft Forschung. Neues aus der Ökologischen Tierhaltung. Ausgewählte Beiträge der Internationalen Tagungen zur Ökologischen Schaf/Ziegen-, Schweine-, Milchkuh- und Geflügelhaltung 2007/2008. Braunschweig.

Richter, M.; Seidel, U.; Wangler, L. (2014): SystemInnovationen – Handlungsoptionen für zukunftsfähige Spitzentechnologien. Working Paper. In: *IIT-PERSPEKTIVE Nr. 17*.

Rothe, E.; Meyer, C. (2002): Komfort- und Erkundungsverhalten für Mastschweine verbessern. In: Bau Briefe Landwirtschaft (Hg.): Praxisgerechte Mastschweinehaltung. Münster-Hiltrup: Landwirtschaftsverl (BFL-Spezial).

Salmano, G.; Mellia, E.; Candiani, D.; Ingravalle, F.; Bruno, R.; Ru, G.; Doglione, L. (2008): Changes in haptoglobin, C-reactive protein and pig-MAP during a housing period following long distance transport in swine. In: *VET J* 177, S. 110–115.

Schmithausen, R. M. (2014): Was können Landwirte gegen die Entstehung und Ausbreitung von Antibiotikaresistenzen und Keimen tun? Ministerium für Klimaschutz, Umwelt, Landwirtschaft, Natur- und Verbraucherschutz des Landes Nordrhein-Westfalen. Düsseldorf, 2014.

Schmithausen, R. M. (2015): Transfer of multidrug-resistant pathogens between humans and animals. Dissertation. Rheinische Friedrich-Wilhelms-Universität, Bonn.

Schmithausen, R. M.; Müller, J.; Schulze-Geisthövel, S. V.; Wilke, T.; Raab, V.; Breuer, O.; Friedrich, A.; Petersen, B. (2013a): Crossing Borders and Crossing Disciplines: Expertenworkshop und Krisenseminar zum Ausbruch eines zoonotischen Infektionserregers in der deutsch-niederländischen Grenzregion. IV. EHECWokshop 2013. LGL Bayern.

Schmithausen, R.; Schulze-Geisthövel, S.; Stemmer, F.; Bierbaum, G.; Hörauf, A. Bekeredjian-Ding I.; Petersen, B. (2013b): Assessment of the risk of antibiotics resistance development in pig farms. In: Nationale Forschungsplattform für Zoonosen (Hg.): National Symposium on Zoonoses Research 2013. Best poster award.

Schmithausen, R. M.; Schulze-Geisthövel, S. V.; Stemmer, F.; El-Jade, M.; Reif, M.; Hack, S.; Meilaender, A.; Montabauer, G.; Fimmers, R.; Parcina, M.; Hoerauf, A.; Exner, M.; Petersen, B.; Bierbaum, G.; Bekeredjian-Ding, I. (2015): Analysis of transmission of MRSA and ESBL-E among pigs and farm personnel. In: *PLOS ONE*.

Schmolke, S. A.; Li, Y. Z.; Gonyou, H. W. (2003): Effect of group size on performance of growing-finishing pigs. In: *J ANIM SCI* 81, S. 874–878.

Schön, H. (2002): Entwicklung der Landbewirtschaftung, Folgerungen für Forschung und Lehre. In: *ROSTOCKER AGRAR- UND UMWELTWISSCHENSCHAFTLICHE BEITRÄGE* Heft 11, S. 77–99.

Schön, H.; Haidn, B.; Wendl, G. (2003): Technische Innovationen in der Nutztierhaltung zur Verbesserung des Tier- und Verbraucherschutzes. In: *ARCH TIERZ DUMMERSTORF* Sonderheft 46, S. 32–42.

Schön, H.; Wendl, G.; Klindtworth, M.; Harms, J. (2001): Precision Lifestock Farming – Konzeption, Stand der Forschung, Zukunftsperspektiven. In: Institut für Agrartechnik der Universität Hohenheim (Hg.): Bau, Technik und Umwelt in der landwirtschaftlichen Nutztierhaltung. Beiträge zur 5. Internationalen Tagung 2001. Stuttgart-Hohenheim, 06.-07.03.2001, S. 1–9.

Schröder, T. (2011): Zukünftige Nutztierhaltung in Deutschland aus Sicht des Tierschutzbundes – Gibt es intensive undnachhaltige Wege? DRV Fachtagung Vieh und Fleisch. Deutscher Tierschutzbund e.V. Montabaur, 22.11.2011.

Schrøder-Petersen, D. L.; Simonsen, H. B. (2001): Tail Biting in Pigs. In: *VET J* 162, S. 196–210.

Schulz, J.; Friese, A.; Klees, S.; Tenhagen, B. A.; Fetsch, A.; Rösler, U.; Hartung, J. (2012): Longitudinal study of the contamination of air and of soil surfaces in the vicinity of pig barns by livestock-associated methicillin-resistant Staphylococcus aureus. In: *APPL ENVIRON MICROBIOL* 78, S. 5666–5671.

Schulze Althoff, G. (2006): Stufenkonzept zum Aufbau überbetrieblicher Informationssysteme für das Qualitäts- und Gesundheitsmanagement in Wertschöpfungsketten der Fleischwirtschaft. Dissertation. Rheinische Friedrich-Wilhelms-Universität, Bonn.

Schulze-Geisthövel, S.; Klauke, T.; Jaeger, F.; Hamer, M.; Petersen, B. (2012): Vergleichende Strukturanalysen zur Charakterisierung von typischen Ursachenkomplexen für Verhaltensanomalie wie Schwanzbeißen beim Schwein innerhalb unterschiedlicher Haltungs- und Managementsysteme. In: *NUTZTIERPRAXIS AKTUELL* 41, S. 12–17.

Schulze-Geisthövel, S.; Schmithausen, R.; Stemmer, F.; El-Sade, M.; Hoerauf, A.; Exner, M.; Bierbaum, G.; Bekeredjian-Ding, I.; Petersen, B. (2014): Occurrence of MRSA and ESBL in different habitats and different stages of the pork production chain. DACH Epidemiologietagung „Tiergesundheit und Ökonomie". Zürich, Schweiz, 2014.

Schulze-Geisthövel, S. V.; Steinmann, M. (2012): Wie sind die Alternativen zu bewerten? In: *FLEISCHWIRTSCHAFT* 92, S. 14–20.

Schumpeter, J. (1931): The Present World Depression: A Tentative Diagnosis. In: *AM ECON REV* 21, S. 179–182.

Schütz, V. (2009): Modell zur Planung von Dienstleistungen für das überbetriebliche Gesundheitsmanagement in der Fleischwirtschaft. Dissertation. Rheinische Friedrich-Wilhelms-Universität, Bonn.

Schütz, V. (2009): Modell zur Planung von Dienstleistungen für das überbetriebliche Gesundheitsmanagement in der Fleischwirtschaft. Dissertation. Rheinische Friedrich-Wilhelms-Universität, Bonn.

Seiler, C.; Berendonk, T. U. (2012): Heavy metal driven co-selection of antibiotic resistance in soil and water bodies impacted by agriculture and aquaculture. In: *FRONT MICROBIOL* 3, S. 399.

SGS Fresenius (2011):): Verbraucherstudie 2011 "Lebensmittelqualität & Verbrauchermacht".

Sheldon, K. M.; Elliot, A. J.; Ryan, R. M.; Chirkov, V.; Kirn, Y.; Wu, C.; Dernir, M.; Sun, Z. (2004): Self- concordance and subjective well-being in four cultures. In: *J CROSS CULT PSYCHOL* 35, S. 209–233.

Simons, J.; Heinen, S.; Hartmann, M. (2011): CSR intern nicht ausreichend kommuniziert – Kommunikation über Unternehmens-verantwortung und Nachhaltigkeit in der Fleischwirtschaft. In: *FLEISCHWIRTSCHAFT* 91 (6), S. 60–63.

Slütter, S. (2013): Approach to use the Engage Exchange Model for information management in crisis communication and animal disease control. Dissertation. Rheinische Friedrich-Wilhelms-Universität, Bonn.

Smith, D. L.; Harris, A. D.; Johnson, J. A.; Silbergeld, E. K.; Morris, J. G. (2002): Animal antibiotic use has an early but important impact on the emergence of antibiotic resistance in human commensal bacteria. In: *P NATL ACAD SCI USA* 99, S. 6434–6439.

Smith, T. C.; Male, M. J.; Harper, A. L.; Kroeger, J. S.; Tinkler, G. P.; Moritz, E. D.; Capuano, A. W.; Herwaldt, L. A.; Diekema, D. J. (2009): Methicillin-resistant Staphylococcus aureus (MRSA) strain ST398 is present in midwestern U.S. swine and swine workers. In: *PLOS ONE* 4, e4258.

Smulders, D.; Hauteklet, V.; Verbeke, G.; Geers, R. (2008): Tail and ear biting lesions in pigs: an epidemiological study. In: *ANIM WELFARE* 17, S. 61–69.

Sommer, M. A. (2009): Epidemiologische Untersuchungen zur Tiergesundheit in Schweinezuchtbeständen unter besonderer Berücksichtigung von Managementfaktoren und des Einsatzes von Antibiotika und Homöopathika. Dissertation. Tierärztliche Hochschule, Hannover.

Spohr, M.; Rau, J.; Friedrich, A. W.; Klittich, G.; Fetsch, A.; Guerra, B.; Hammerl, J. A.; Tenhagen, B. A. (2011): Methicillin-Resistant Staphylococcus aureus (MRSA) in Three Dairy Herds in Southwest Germany. In: *ZOONOSES PUBLIC HLTH* 58, S. 252–261.

Srinongkote, S.; Smriga, M.; Nakagawa, K.; Toride, Y. (2003): A Diet Fortified with l -lysine and l -arginine Reduces Plasma Cortisol and Blocks Anxiogenic Response to Transportation in Pigs. In: *NUTR NEUROSCI* 6, S. 283–289.

Stafford, K. J. (2010): Tail biting: an important and undesirable behaviour of growing pigs. In: *VET J* 186, S. 131–132.

Statistisches Bundesamt (2010): Land- und Forstwirtschaft, Fischerei. Landwirtschaftliche Berufsbildung der Betriebsleiter/Geschäftsführer Landwirtschaftszählung. Agrarstrukturerhebung 2010.

Statistisches Bundesamt (2010): Land- und Forstwirtschaft, Fischerei. Arbeitskräfte. Landwirtschaftszählung 2010.

Steverink, I. M. (Hg.) (2011): „Beter Leven“ ein Label für einen besseren Tierschutz. truefoodprojects. DRV Fachtagung Vieh und Fleisch. Montabaur, 22.11.2011.

Steverink, I. M. (2011): „Beter Leven“ ein Label für einen besseren Tierschutz. truefoodprojects. DRV Fachtagung Vieh und Fleisch. Montabaur, 22.11.2011.

Striezel, A. (2005): Leitfaden der Nutztiergesundheit. Ganzheitliche Prophylaxe und Therapie. Stuttgart: Sonntag-Verlag.

Strommenger, B.; Bartels, M. D.; Kurt, K.; Layer, F.; Rohde, S. M.; Boye, K.; Westh, H.; Witte, W.; Lencastre, H. de; Nübel, U. (2014): Evolution of methicillin-resistant Staphylococcus aureus towards increasing resistance. In: *J ANTIMICROB CHEMOTH* 69, S. 616–622.

Strommenger, B.; Kettlitz, C.; Werner, G.; Witte, W. (2003): Multiplex PCR assay for simultaneous detection of nine clinically relevant antibiotic resistance genes in Staphylococcus aureus. In: *J CLIN MICROBIOL* 41, S. 4089–4094.

Sundrum, A. (Hg.) (1995): Tiergesundheit. zum Verständnis eines komplexen Sachverhaltes aus biologischer, ethologischer, tierärztlicher, ökologischer und philosophischer Sicht. Hamburg: Verlag Dr. Kovač.

Svendsen, O. (2006): Castration of piglets under carbon dioxide (CO2) anaesthesia. In: *J VET PHARMACOL THER* 29 (1), S. 54–55.

Taylor, A. A.; Weary, D. M. (2000): Vocal responses of piglets to castration: identifying procedural sources of pain. In: *APPL ANIM BEHAV SCI* 70, S. 17–26.

Taylor, N. R.; Main, D. C. J.; Mendl, M.; Edwards, S. A. (2010): Tail-biting: A new perspective. In: V*ET J* 186, S. 137–147.

Tenhagen, B. A.; Fetsch, A.; Stührenberg, B.; Schleuter, G.; Guerra, B.; Hammerl, J. A.; Hertwig, S.; Kowall, J.; Kämpe, U.; Schroeter, A.; Bräunig, J.; Käsbohrerm A.; Appel, B. (2009): Prevalence of MRSA types in slaughter pigs in different German abattoirs. In: *VET REC* 165, S. 589–593.

The European Committee on Antimicrobial Susceptibility Testing (EUCAST): Clinical breakpoints (Bacterial v3.1). Central Hospital, 351 85 Växjö, Sweden.

Theuvsen, D. (Hg.) (2009): Virtuelles Qualitätsmanagement: Simulationsgestützte Auslegung kostenoptimierter Qualitätsregelkreise. 11/2009. Aachen: Shaker Verlag.

Tholen, E.; Frieden, L. (2010): Züchterische Möglichkeiten zur Vermeidung von Ebergeruch. 8. Schweine-Workshop „Neue Herausforderungen für die Schweinezucht“. Uelzen, 23.02.2010.

Threlfall, E. J.; Ward, L. R.; Frost, J. A.; Willshaw, G. A. (2000): The emergence and spread of antibiotic resistance in food-borne bacteria. In: *INT J FOOD MICROBIOL* 62, S. 1–5.

Tian, G. B.; Wang, H. N.; Zou, L. K.; Tang, J. N.; Zhao, Y. W.; Ye, M. Y. Tang, J. Y.; Zhang, Y.; Zhang, A. Y.; Yang, X.; Xu, C. W.; Fu, Y. J. (2009): Detection of CTX-M-15, CTX-M-22, and SHV-2 extended-spectrum beta-lactamases (ESBLs) in Escherichia coli fecal-sample isolates from pig farms in China. In: *FOODBORNE PATHOG DIS* 6, S. 297–304.

Tierschutzgesetz (2006): i. d. F. der Bekanntmachung vom 18. Mai 2006, (BGBl. I S. 1206, 1313), letzte Änderung durch Art. 3 des Gesetzes vom 28. Juli 2014 (BGBl. I S. 1308-1309). Online verfügbar unter http://www.gesetze-im-internet.de/tierschg/BJNR012770972.html.

Tierschutzgesetz (2006): Tierschutzgesetz in der Fassung der Bekanntmachung vom 18. Mai 2006 (BGBl. I S. 1206, 1313), letzte Änderung durch Artikel 20 des Gesetzes vom 9. Dezember 2010 (BGBl. I S. 1934).

TNS Emnid (2012): Das Image der deutschen Landwirtschaft: Ergebnisse einer Repräsentativbefragung. Online verfügbar unter http://www.ima-agrar.de/fileadmin/redaktion/download/image-studie/2012/ima-imastudie-landwirtschaft_charts-2012.pfd.

Tölle, K. H. (2009): Schwanzbeißen bei Mastschweinen – Die Urachen sind vielfältig. In: *LANDPOST*, S. 40–41.

van Cleef, B. A.; Verkade, E. J.; Wulf, M. W.; Buiting, A. G.; Voss, A.; Huijsdens, X. W.; van Pelt, W.; Mulders, M. N.; Kluytmans, J. A. (2010): Prevalence of livestock-associated MRSA in communities with high pig-densities in The Netherlands. In: *PLOS ONE* 5, e9385.

van de Weerd, H. A. (2005): The development of harmful social behaviour in pigs with intact tails and different enrichment backgrounds in two housing systems. In: *ANIM SCI* 80, S. 289.

van de Weerd, H. A.; Docking, C. M.; Day, J. E. L.; Breuer, K.; Edwards, S. A. (2006): Effects of species-relevant environmental enrichment on the behaviour and productivity of finishing pigs. In: *APPL ANIM BEHAV SCI* 99, S. 230–247.

van den Broek, I. V.; van Cleef, B. A.; Haenen, A.; Broens, E. M.; van der Wolf, P. J.; van den Broek, M. J.; Huijsdens, X. W.; Kluytmans, J. A.; van de Giessen, A. W.; Tiemersma, E. W. (2009): Methicillin-resistant Staphylococcus aureus in people living and working in pig farms. In: *EPIDEMIOL INFECT* 137, S. 700–708.

van der Fels-Klerx, H. J.; Puister-Jansen, L. F.; van Asselt, E. D.; Burgers, S. L. (2011): Farm factors associated with the use of antibiotics in pig production. In: *J ANIM SCI* 89, S. 1922–1929.

van Duijkeren, E.; Ikawaty, R.; Broekhuizen-Stins, M. J.; Jansen, M. D.; Spalburg, E. C.; Neeling, A. J. de; Allaart, J. G.; van Nes, A.; Wagenaar, J. A.; Fluit, A. C. (2008): Transmission of methicillin-resistant Staphylococcus aureus strains between different kinds of pig farms. In: *VET MICROBIOL* 126, S. 383–389.

van Loo, I.; Huijsdens, X. W.; Tiemersma, E. W.; Neeling, A. de; van de Sande-Bruinsma, N.; Beaujean, D.; Voss, A.; Kluytmans, J. A. (2007): Emergence of methicillin-resistant Staphylococcus aureus of animal origin in humans. In: *EMERG INFECT DIS* 13, S. 1834–1839.

Voets, G. M.; Platteel, T.; Fluit, A. C.; Scharinga, J.; Schapendonk, C. M.; Stuart, J. C.; Bonten, M. J. M.; Hall, M. A.; Group, N. E. S. W. (2012): Population distribution of Beta-lactamase conferring resistance to third-generation cephalosporins in human clinical Enterobacteriaceae in the Netherlands. In: *PLOS ONE* 7, e52102.

Vom Brocke, A. L. (2014): A step to reducing tail biting in finisher pigs: Can a management tool help pigs and farmers? Dissertation. Georg-August-Universität, Göttingen.

Vom Brocke, A. L.; Madey, D. P.; Gauly, M.; Schrader, L.; Dippel, S. (2015): Training veterinarians and agricultural advisers on a novel tool for tail biting prevention. In: *VET REC OPEN* 2.

Voßkamp, R. (2002): Innovationsökonomik II. In: M. Erlei und M. Lehmann-Waffenschmidt (Hg.): Curriculum Evolutorische Ökonomik. Lehrkonzepte zur evolutorischen Ökonomik. Marburg: Metropolis-Verl, S. 57–84.

Wagenaar, J. A.; Yue, H.; Pritchard, J.; Broekhuizen-Stins, M.; Huijsdens, X.; Mevius, D. J.; Bosch, T.; van Duijkeren, E. (2009): Unexpected sequence types in livestock associated methicillin-resistant Staphylococcus aureus (MRSA): MRSA ST9 and a single locus variant of ST9 in pig farming in China. In: *VET MICROBIOL* 139, S. 405–409.

Waldmann, K. H.; Hoppe, M.; Steigmann, M.; Andreae, A.; Kaestner, S.: Comparison of anaesthetic effects during piglet castration by using commercial inhalation systems with carbon dioxide and isoflurane. In: S. D'Allaire und R. Friendship (Hg.): Proceedings of the 21st International Pig Veterinary Society Congress: IPVS 2010. Vol. 1: oral presentations Vancouver, Canada, 18.-21.07.2010, S. 249. Online verfügbar unter http://www.ipvs2010.com/PDFs/IPVS-Oral&PosterProceedings(Aug10-10).pdf.

Waldmann, K. H.; Wendt, M. (2003): Strategie einer Risikominimierung in der Schweineproduktion. In: *GROSSTIERPRAXIS* 3, S. 24–26.

Walker, P. K.; Bilkei, G. (2006): Tail-biting in outdoor pig production. In: *VET J* 171, S. 367–369.

Weckenmann, A.; Bokkjans, M. (2009): Virtuelles Qualitätsmanagement: Simulationsgestützte Auslegung kostenoptimierter Qualitätsregelkreise. In: D. Theuvsen (Hg.): Virtuelles Qualitätsmanagement: Simulationsgestützte Auslegung kostenoptimierter Qualitätsregelkreise. 11/2009. Aachen: Shaker Verlag, S. 151–165.

Weiler, U.; Font I Furnols, M.; Fischer, K.; Kemmer, H.; Oliver, M. A.; Gispert, M.; Dobrowolski, A.; Claus, R. (2000): Influence of differences in sensitivity of Spanish and German consumers to perceive androstenone on the acceptance of boar meat differing in skatole and androstenone concentrations. In: *MEAT SCI* 54 (3), S. 297–304.

Welz, Matthias (1994): Bewertung von Erkrankungen als qualitätshemmende Faktoren mit Hilfe der Fehler-Möglichkeits- und Einfluß-Analyse (FMEA) im Rahmen der Erzeugung von Qualitätsfleisch. Aachen: Shaker.

Widowski, T. (2002): Causes and prevention of tail biting in growing pigs: a review of recent search. In: Proceedings of the 2nd London Swine Conference. The Pork Industry in the 21st Century – Conquering the Challenges, S. 47–56.

Wieler, L. H.; Ewers, C.; Guenther, S.; Walther, B.; Lübke-Becker, A. (2011): Methicillin-resistant staphylococci (MRS) and extended-spectrum beta-lactamases (ESBL)-producing Enterobacteriaceae in companion animals: Nosocomial infections as one reason for the rising prevalence of these potential zoonotic pathogens in clinical samples. In: *INT J MED MICROBIOL* 301 (8), S. 635–640.

Wilke, T.; Schulze-Geisthövel, S.; Petersen, B. (2014): On-farm biosecurity management. In: B. Petersen, M. Nüssel und M. Hamer: Quality and risk management in agri-food chains. Wageningen: Wageningen Academic Publishers, S. 190–200.

Wissmann, A.; Popp, W.; Hilken, G. (2011): Methicillin-resistente Staphylococcus aureus in der Veterinärmedizin und dessen Bedeutung im Gesundheitswesen. In: *KRANKENHAUS-HYGIENE + INFEKTIONSVERHÜTUNG* 33, S. 126–129.

Witte, W.; Klare, I. (1999): Antibiotikaresistenz bei bakteriellen Infektionserregern - Mikrobiologisch-epidemiologische Aspekte. In: *BUNDESGESUNDHEITSBLA* 42, S. 8–16.

Woll, R.; Uhlemann, M. (Hg.) (2012): Vielfalt Qualität - Tendenzen im Qualitätsmanagement. Bericht zur GQW-Jahrestagung 2012 in Cottbus. Aachen: Shaker.

Wulf, M. W.; Verduin, C. M.; van Nes, A.; Huijsdens, X.; Voss, A. (2012): Infection and colonization with methicillin resistant Staphylococcus aureus ST398 versus other MRSA in an area with a high density of pig farms. In: *EUR J CLIN MICROBIOL* 31, S. 61–65.

Zamaratskaia, G.; Squires, E. J. (2009): Biochemical, nutritional and genetic effects on boar taint in entire male pigs. In: *ANIMAL* 3, S. 1508–1521.

Zander, K.; Hamm, U. (2010): Consumer preferences for additional ethical attributes of organic food. In: *FOOD QUAL PREFER* 21 (5), S. 495–503.

Zander, K.; Isermeyer, F.; Bürgelt, D.; Christoph-Schulz, I.; Salamon, P.; Weible, D. (2013): Erwartungen der Gesellschaft an die Landwirtschaft. Abschlussbericht: Stiftung Westfälische Landschaft.

List of Figures

List of Tables

Acknowledgements

Als allererstes möchte ich mich bei Ihnen, Frau Prof. Dr. Brigitte Petersen, für die Überlassung des Themas bedanken und für Ihre unermüdliche Bereitschaft, mich bei meinen Forschungsarbeiten zu unterstützen, aber auch für ihre Anleitungen und Ermutigungen während der letzten vier Jahre. Sie hatten oft Zeit für Diskussionen und tolle Ideen. Für all das danke Ihnen sehr!

Ich möchte mich auch bei Herrn Prof. Dr. Wolfgang Büscher für die freundliche Übernahme des Zweitgutachtens bedanken.

Ich bedanke mich beim ganzen PGM-Team von 2011-2015 für den wunderbaren Teamgeist. Ich habe die Zeit im Trubel, aber auch das relativ kleine Team sehr genossen. Vielen lieben Dank besonders an Frau Petra Heinrich für Alles. Ohne Eure Hilfe und Wissen wäre es sehr viel schwieriger gewesen, diese interessanten Ergebnisse zu erhalten. Außerdem möchte ich mich bei allen Bachelor- und Master-Studenten unter meiner Betreuung für ihre erfolgreiche Zusammenarbeit bedanken.

Weiterhin möchte ich mich bei Herrn Prof. Dr. Friedhelm Jaeger und Herrn Dr. Martin Hamer bedanken, die mir die Chance gegeben haben, meine Diplomarbeit in China durchzuführen. Der Aufenthalt dort war eine der größten Erfahrungen, die ich bisher gemacht habe. Und vielleicht wäre meine Dissertation ohne die Arbeit dort nie zustande gekommen. Deshalb möchte ich an dieser Stelle auch nochmal Herrn Prof. Zhu, Herrn Prof. Lee und meinen Studenten in Ya´an danken.

Auch bei Frau PD Dr. Isabelle Bekredjian-Ding, Frau Prof. Dr. Gabriele Bierbaum, Herrn Prof. Dr. Martin Exner und ihren Teams möchte ich mich für Ihre Unterstützung und die Laborarbeiten bedanken. Vielen Dank an die Raiffeisen Viehvermarktung GmbH, die Landwirte und Tierärzte und die Erzeugergemeinschaft Osnabrück und ihre Landwirte aber auch an die unbekannten Landwirte, die den Fragebogen beantwortet haben. Ohne diese Unterstützung hätte ich die Doktorarbeit nicht schreiben können. Desweiteren möchte ich mich bei den Firmen Westfleisch und Tönnies sowie ihren Mitarbeitern bedanken, ohne die die Probeentnahme am Schlachthof nicht möglich gewesen wäre. Im Besonderen bei Herrn Hans-Jörg Eynck, der in zwei Kapitel involviert war. Vielen Dank auch an die Gruppe von Frau Prof. Dr. Dr. Helga Sauerwein für die Laborarbeiten. Herzlichen Dank auch an Prof. Dr. Ernst Berg und sein Team für die sehr gute Teamarbeit bei dem Projekt der Landwirtschaftlichen Rentenbank und an die Experten, die hier ein Interview gaben. Weiterhin möchte ich mich bei allen Mitautoren der einzelnen Kapitel der Arbeit recht herzlich bedanken.

Ich möchte mich auch für die finanzielle und logistische Unterstützung der Projekte FinQ NRW, Safeguard, QUARISMA und SiLeBAT bedanken, die von der Europäischen Union, dem BMBF und dem Land Nordrhein-Westfalen finanziert wurden.

Mein besonderer Dank gilt meiner Mutter, die Ricarda und mich in der stressigen Zeit der Probenahme im Sommer 2012 aufgenommen hat und uns in jeder Hinsicht unterstützt hat. Aber auch ohne Ricarda, wäre diese Arbeit nicht möglich gewesen. Ganz lieben Dank, für die unvergessliche Zeit! Und natürlich möchte ich mich auch bei meinen Geschwistern, meinen Großeltern und bei meinen Freunden bedanken, die immer für mich da waren, mich geerdet haben und durch diese turbulente Zeit begleitet haben.