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IN THE AGE OF PANDEMICS, CONNECTING FOOD SYSTEMS AND HEALTH: A GLOBAL ONE HEALTH APPROACH

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1. THE CHALLENGES

Local, regional and global food security are affected by the occurrence of epidemics of zoonotic infectious diseases, caused by pathogens that spillover from animals to humans. Currently, this is clearly illustrated by the COVID-19 crisis. Diseases that affect animals and plants also continue to disrupt food security by interrupting the food supply. A One Health approach embraces the notion that the health of animals, people, plants and the environment are inextricably connected. Conversely, climate change, urbanization and mobility innovations should evaluate the risk for new and (re-)emerging human, animal and plant pathogens.

The COVID-19 pandemic lays bare the complex connections between food systems and health. In addition, the pandemic exposes how human health is affected by socio-economic status and how health affects economic and social systems in return. The current pandemic was not the first, nor will it be the last. Here, we discuss the link between global food security and healthy people, animals, plants and environment, and how we can better prepare for, and minimize the chance of, future pandemics. We conclude that both public and private parties should strengthen their One Health approach to jointly realize resilient and strong global health and agri-food systems.

Interconnection between ecosystems, human and animal health - zoonotic infectious diseases

COVID-19 is only one example of a zoonosis, a disease caused by the 'successful' transmission, spillover, of a pathogen from animals to humans. SARS-CoV-2 emerged from wildlife. Similarly, ~60% of emerging infectious diseases in humans originated from animals, and ~70% thereof originated from wildlife. Such spillover events occur most commonly where the agri-food system interfaces with natural ecosystems, as this is where humans, domesticated animals and wildlife interact.

Through humanity's long history with animal husbandry and consumption, hygiene practices have evolved, reducing the likelihood of successful spillover events (e.g., food safety, clean water, and elimination of rodents from shelters). However, increasing mobility, population densities and urbanization, as well as the growing length and scale of the global food supply chains, and pressure on natural ecosystems by chang-

ing land use, have created new challenges and put the need for adaptation of current surveillance and intervention strategies in sharper focus.

Poor human health facilitates infectious disease spread

Sub-optimal human health adds to the favorable conditions for pathogen transmission. Poor nutritional status and impaired general health of individuals and populations, for example due to the absence of nutritious foods and access to (affordable) health care, increases susceptibility to infectious diseases. Many of the common non-infectious diseases, including obesity, diabetes, cancer and cardio-vascular diseases, impair the body's immune response. These chronic conditions lower barriers to successful pathogen spillover from animals to humans, and subsequent pathogen transmission between people. Similar to other infectious diseases, COVID-19 disproportionately affects those with poor nutritional status and underlying health issues.

2. IMPACT OF ZOONOTIC INFECTIOUS DISEASES ON FOOD SECURITY

Direct impacts

Large disease outbreaks disrupt the workforce and supply chain. Both the disease and the measures implemented to combat the COVID-19 pandemic disabled, and continue to disable, part of the workforce. Such disruptions in the workforce affect the food supply and in many cases the workers' income or the economic viability of businesses in the food system. In addition, restrictions on travel limit the movement of workers, disrupting harvest and processing operations. Similarly trade restrictions limit the movement of goods, affecting supply and demand.

Indirect impacts

Cascading effects of the pandemic increase price volatility, disrupt food security and the livelihoods of those dependent on the food supply chain. COVID-19, similar to for example past influenza outbreaks, has changed consumption patterns. Combined with travel and trade restrictions this resulted in, among other things, uncertainties in the food supply chain, that led to volatility in producer and consumer prices. These disrupted markets most severely affect vulnerable populations, e.g., low-income families - leaving them unable to acquire nutritious food- or small farm operations. Furthermore, the COVID-19 pandemic is estimated to have put about a third of the jobs in the food value chain at risk (451 million jobs out of ~1.3 billion), disrupting the livelihoods of ~ 1 billion people.

SARS-CoV-2 and other infectious pathogens in the food chain

Zoonotic and other infectious pathogens can be transmitted via many different routes, including water and food products. The main transmission route of SARS-CoV-2 is the respiratory route, but anecdotal evidence is available of detection of SARS-CoV-2 genetic material in frozen products (e.g., ice-cream). Currently, February 2021, the movement of SARS-CoV-2 through the cold chain is still considered as a possible route of introduction of the pathogen to the urbanized center of Wuhan, China, from where it spread across the world.

The presence of pathogens in food systems may trigger interventions to stop pathogen spread. Although we focus on zoonotic pathogens here, animal and plant diseases and pests should be kept in mind. Similar to zoonotic pathogens, the range and outbreak frequencies of these disruptors of the food supply chain and health are expected to change due to the effects of climate change. Interventions to mitigate zoonotic and notifiable animal and plant pathogens, including transport bans, destruction of crops, and culling, directly impact the food chain and the business and livelihoods of those relying on it.

3. ADAPTING THE AGRI-FOOD SYSTEM TO LIMIT PATHOGEN RISK

Reducing the likelihood of spillover and onwards transmission risk of pathogens can be achieved through i) reducing the need for natural habitat disruption, ii) smart management of both sides of the interface between natural ecosystems and the agri-food system, and vigilance at the human- animal interface within the agri-food system, and iii) improving overall human, animal and environmental health.

Decreasing habitat disruption through sustainable intensification of land use

Sustainable intensification of land use could aid in limiting contact between humans and livestock with natural ecosystems and wildlife. To continue to meet the growing demand for food, further acreage expansion by conversion of natural habitats to agricultural lands is expected in several regions of the world. The pressure on natural ecosystems, caused by the expanding agri-food system, tends to negatively affect the biodiversity, resilience and health of wildlife, and increases the frequency of human, domestic animal and wildlife contact. These factors all contribute to increasing the chance of spillover occurring. Hence the argument to reduce natural habitat disruption, and utilize sustainable intensification practices instead to meet the growing food demand.

Smart management and vigilance at the interfaces by surveillance and readiness to intervene

Risk assessments should inform surveillance and readiness strategies to optimize pathogen detection and intervention. Over the past decades we have created a more-and-more connected, and ready, network for pathogens to spread, with the agri-food system being an integral part of this conduit for the onwards spread of pathogens. Here the domains of food security, safety and health clearly overlap: from hunting practices to livestock farming, from butchering practices at home to slaughterhouses, from trade of live-animals on markets and unsafe food preparation practices to contaminated food products in supermarkets, and the length and scale of parts of the global food system.

Detection efforts aimed at preventing pathogen spillover and spread throughout these highly connected networks can be optimized by mapping and assessing the risk, specifically at the human and domestic animal - wildlife interface and in the transport (cold) chain. Targeted sampling and surveillance throughout the system, complemented by appropriate hygiene and biosecurity measures, form the first steps to preventing shocks to the food system and health.

Optimized surveillance at the human-domestic animal-wildlife interfaces may enable early detection of (re)emerging pathogens and unexplained disease symptoms (e.g., undiagnosed pneumonia in the case of SARS-CoV-2). This early detection provides the opportunity for early interventions, and re-design of the system. Importantly, clear communication with producers and the public about biosecurity measures, and a rapid and strong unified response are needed to prevent and control potential outbreaks.

Improving overall human, animal and environmental health - A Global One Health approach

Through active engagement with learning and recovery steps following the current pandemic crisis, governments, the private sector and society as a whole, have the opportunity to improve, and work towards, more resilient markets, and create systems to reduce strain on our environment and to keep vulnerable populations sheltered from shocks - instead of amplifying their vulnerability (as is happening in COVID-19).

Food security is essential to reducing malnutrition, and results in improved human health and wellbeing, and a human population that is less susceptible to pathogens (e.g., reducing undernutrition, obesity, and resulting diseases). Governmental actions can lead the way to provide food security, by ensuring the functioning of the food supply chain and food systems (e.g., minimizing disruption in trade of goods, providing employment services to migrant workers), and by communicating clearly to avoid mass panic, and disproportional consumer behavior during disease outbreaks. The private sector can weigh their impact on health, considering that their supply chain may be disrupting natural habitats, and that unknown pathogens may emerge at their farms, be transported in their cold chains, or disproportionately affect their staff. These actions, serving the global and national good, should be governed through global institutions to ensure governance of the food system and health for all.

The interconnectedness of environmental, human and animal health can be leveraged in food systems to find unconventional opportunities to improve health. Further research and an improved understanding of the role of the food system in the context of Global One Health may provide additional entry points via the food system for sustainable, culturally acceptable and economically feasible interventions.

4. TOWARDS FOOD SYSTEM RESILIENCE

Resilient systems allowing for rapid recovery are needed to minimize direct and indirect health effects of shocks to the food system. Shocks, small and large, will continue to disrupt the food system, although efforts to prevent and minimize shocks (as described above for zoonotic infectious diseases) may reduce the frequency and severity of shocks.

Managing the interdependencies between health and the food system to improve health for all presents many challenges, including a change in mindset. Nevertheless, the dots between the food system, and environmental, animal, plant and human health are becoming more connected in global, regional and national initiatives. For example, the materiality matrix in corporate sustainability reports, wherein stakeholder interests and a company's social, economic, and environmental impact are weighted. Also, the European commission is moving towards a code of conduct for participants in the food supply chain. Such a code of conduct could be considered at a global level. Most recently, September 2020, the creation of a One Health High-Level expert council by UN Environment, FAO, OIE and WHO to address risks at the human-animal-environment interface. When consumers, producers and governments combine their efforts and take a Global One Health approach to re-design the agri-food system, significant steps can be made towards food system resilience and better health.

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