Food and Agriculture Organization
of the United Nations

FAO Joint Centre for Zoonotic Diseases and Antimicrobial Resistance (CJWZ) report

Expert consultative meeting on a One Health approach to reducing food loss and waste in relation to animal diseases and antimicrobial resistance

Virtual meeting

13 October 2022

Contents

Acknowledgements

FAO would like to express its sincere gratitude to all of the experts who participated in this meeting, as well as the two keynote speakers.

Meeting participants

The online expert consultation was attended by 35 individuals worldwide.

Fadi	Al natour	ADAFSA
Mohammad	Al-Salem	PAFN
Abdullah	Alsalem	PAFN
Bashiru	Boi Kikimoro	National Laboratory for Animal Health, Ghana
Massimo	Canali	University of Bologna
Anita	Caulkool	Ministry of Health and Sanitation, Sierra Leone
Carlos	Chaves	Laboratorio Central Agroalimentar-SNCQA
Chuanchuen	Rungtip	Chulalongkorn University
Kate	Huebner	FDA
Ahmed	Kablan	USAID
Priya	Kadam	FDA
Marla	Keller	FDA
Blanca Cristina	Olarte Pinilla	Ministry of Health, Colombia
Max	Renton	VMD, UK
Olivier	Rukundo	Rwanda Consumers Rights Protection (ADECOR)
Jonathan	Rushton	University of Liverpool
Cristina	Santos	DGAV
Paula	Teixeira	Universidade Católica Portuguesa
Annarita	Valenzano	European Commission
Chang	Cai	FAO
Ihab	El masry	FAO
Akiko	Kamata	FAO
Jieun	Kim	FAO
Artem	Metlin	FAO
Divine	Njie	FAO
Irene	Ouoba	FAO
Jorge	Pinto Ferreira	FAO
Andriy	Rozstalnyy	FAO
Daniela	Ruehl	FAO
Huyam	Salih	FAO
Camila	Santos	FAO
Marion	Selosse	FAO
Nianjun	Shen	FAO
Junxia	Song	FAO
Jose	Urdaz	FAO
Antonio	Valcare	FAO

Invited speakers

Jonathan Rushton
Professor of Animal Health and Food Systems Economics
Director of the Global Burden of Animal Diseases programme
Centre of Excellence for Sustainable Food Systems
University of Liverpool
jrushton@liverpool.ac.uk

Rungtip Chuanchuen
Center of Antimicrobial Resistance Monitoring in Foodborne Pathogens (in cooperation with WHO)
Global Infections Network: South-East Asia and Western Pacific region
Research Unit in Microbial Food Safety and Antimicrobial Resistance
Chulalongkorn University, Bangkok
FAO Reference Centre for Antimicrobial Resistance
chuanchuen.r@gmail.com

Report written by Fanette Fontaine (FAO)

Acronyms

AMR	antimicrobial resistance
AMU	antimicrobial use
ARG	antibiotic resistant gene
CJWZ	Joint FAO/WHO Centre for Zoonotic Diseases and AMR
FAO	Food and Agriculture Organization of the United Nations
FLW	food loss and waste
GHG	greenhouse gas
LMICs	low- and middle-income countries
MIA	medically important antimicrobials
MGEs	mobile genetic elements
SDG	Sustainable Development Goal
UNEP	United Nations Environment Programme
WHO	World Health Organization
WWTP	Waste water treatment plant

Executive summary

The Food and Agriculture Organization of the United Nations (FAO) is leading an international effort to halve per capita food waste by 2030, a goal established under the Sustainable Development Goals (SDGs). As part of this effort, FAO has developed the Voluntary Code of Conduct for Food Loss and Waste Reduction, with specific articles on cutting food loss and waste (FLW) in the context of animal disease and antimicrobial resistance (AMR). Through the Joint FAO/World Health Organization (WHO) Centre for Zoonotic Diseases and AMR (CJWZ), FAO aims to identify measures and innovative practices through a One Health approach that can help to reduce FLW while combating the spread of AMR and preventing disease in food animals.

As a first step in this initiative, an online expert consultation was held in October 2022 on a "One Health approach to reducing food loss and waste (FLW) – in relation to animal diseases and antimicrobial resistance (AMR)". The purpose was to assess and plan solutions to the issue based on findings on interconnections between FLW, AMR and zoonotic diseases.

The expert consultation was attended by 35 individuals from governmental institutions and academia in Asia, Europe, the Near East, North and South America. Sixteen participants from FAO attended. The consultation was introduced by Junxia Song and Divine Njie of FAO. Two international speakers – Jonathan Rushton of the University of Liverpool (UK) and Rungtip Chuanchuen of Chulalongkorn University, Thailand – gave presentations.

The purpose of the expert consultation was to:

- collect expert opinion and generate scientific discussion on the impact of animal diseases and AMR on FLW;
- determine the influence of FLW management (food waste disposal) on the transmission of AMR and pathogens; and
- use a One Health approach to identify measures and innovative practices that countries could adopt to reduce FLW while combating the spread of AMR and preventing disease in food animals.

The main conclusions as regards FLW and AMR related to:

- the relevance of considering interconnections between FLW and AMR;
- the lack of data on the fate of AMR in food waste and how it could contribute to the spread of AMR in the environment; and
- the lack of data on economic impact.

The consultation made the following recommendations:

- evaluate the state of knowledge on interconnections between FLW, AMR and zoonotic diseases;
- map potential AMR risks in the food value chain and different FLW treatment processes;
- improve data collection;
- raise awareness;
- investigate innovative strategies to reduce FLW while tackling AMR issues;
- improve FLW treatment processes to reduce AMR;
- develop guidelines for FLW management to avoid the spread of AMR; and
- promote resource mobilization at national level.

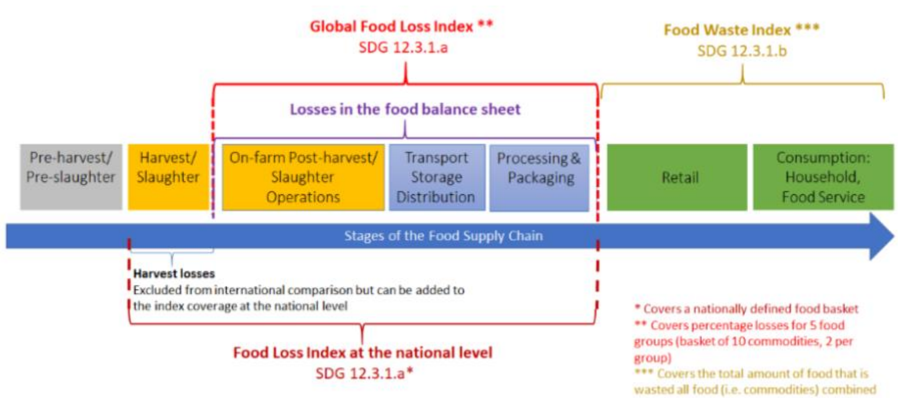
Introduction

The world is facing multiple challenges that are closely linked to the agrifood system, including a climate crisis, food insecurity, AMR and malnutrition. How the global agrifood system will feed a growing global population, estimated to reach 10 billion by 2050, by minimizing the impacts on natural resources, ecosystems and the environment is an overarching concern. Efforts are required to put agrifood systems on a sustainable trajectory.

Around the world, about one-third of all food produced for human consumption – 1.3 billion tonnes – is lost or wasted each year. FLW is the decrease in quantity or quality of food along the food supply chain (FAO, 2019) and results from poorly functioning agrifood systems. The loss and waste stages are categorized according to the below definitions (Figure 1):

- **Food loss** is defined as the decline in quantity or quality of food resulting from decisions and actions by food supply-chain actors from the production stage onwards, excluding retailers, food service providers and consumers. In the context of this workshop, only losses traditionally termed "postharvest" were considered – that is, right after the primary production stage (preharvest/pre-slaughter in Figure 1). Losses in productivity were not taken into account. Taking cattle as an example, if a bull should have been slaughtered at 950 kg but, due to disease or another factor, was slaughtered at 650 kg, that 300kg difference would not be considered a loss, as it happened in the primary production stage (preharvest/pre-slaughter). An estimated 14 per cent of the world's food is lost between harvest and retail.
- **Food waste** is the decline in the quantity or quality of food resulting from decisions and actions by retailers, food service providers and consumers. It is estimated at about 1.3 billion tonnes per year globally. Approximately 17 per cent of the world's food is wasted at the retail and consumption levels.

Figure 1: The different stages at which food loss and waste can happen along the food supply chain



Source: FAO. 2022. *Voluntary Code of Conduct for Food Loss and Waste Reduction*. Rome. https://doi.org/10.4060/cb9433en.
Note: SDG Indicator 12.3 on global FLW aims "by 2030, to halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including postharvest losses".

FLW has societal implications through food security, the economy and the environment. It comes at a time when 828 million people are undernourished and 3.1 billion are without access to healthy diets worldwide (FAO, IFAD, UNICEF,WFP and WHO, 2022). FLW also causes massive financial losses and squanders natural resources. It is a major contributor to environmental damage, with a strong carbon footprint. If FLW were a country, it would be the third-largest emitter of greenhouse gases (GHGs) after China and the United States of America, accounting for between 8 percent and 10 percent of global GHGs. FLW is estimated to have a water footprint of 250 km^3, while 1.4 billion hectares of land (28 percent of the world's agricultural area) are used annually to produce food that is lost or wasted (FAO, 2013). In addition to the energy and resources wasted on growing, transporting and processing this food, improper food waste management (by recycling and upcycling through circular strategies and proper disposal) can pose additional threats.

Foods of animal origin (such as meat, milk, eggs and fish/seafood) account for about 12 percent of global FLW and have a higher economic value than commodities (Lipinski, 2020). They also have a higher environmental footprint, as meat and animal products account for 40 percent of the GHGs emitted by food waste. Milk and meat products are the main culprits when it comes to land use, accounting for approximately 80 percent of the total land used by food waste products (FAO, 2013). Foods of animal origin are also a significant source of AMR in the food chain.

Moreover, the food supply is exposed to animal disease outbreaks and the spread of resistant pathogens resulting from the excessive use and abuse of antimicrobials. Substantial amounts of animals and products of animal origin are being destroyed due to the detection of pathogens and drug residues at the post-slaughter stage, leading to food loss. In addition, antimicrobial-resistant microorganisms can potentially be found in food waste and participate in the spread of AMR in the environment, with a possible impact on both animal and human health. It is important, therefore, to evaluate how the two serious issues of AMR and FLW are interconnected.

Background

Action to reduce FLW is needed to improve nutrition, food security and the sustainability of the food system. FAO has developed the Voluntary Code of Conduct for Food Loss and Waste Reduction in response to a request by the twenty-sixth session of the FAO Committee on Agriculture. The code of conduct contains specific articles on the reduction of FLW in the context of animal diseases and AMR (Annex 2) (FAO, 2022).

In parallel, AMR is a major global threat to human and animal health. AMR has implications for food safety, food security and the economic well-being of millions of farming households. Through CJWZ, FAO is coordinating efforts to address AMR and to reduce the need for antimicrobial use (AMU) in the food and agriculture sectors by implementing the FAO Action Plan on AMR 2021–2025.

The One Health approach will help to foster an integrated vision of the interconnections between FLW and AMR. According to the One Health High-Level Expert Panel (OHHLEP), "One Health is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals and ecosystems. It recognizes that "the health of humans, domestic and wild animals, plants, and the wider environment (including ecosystems) are closely linked and inter-dependent" (FAO, UNEP, WHO and WOAH, 2021). CJWZ aims to identify measures and innovative practices using a One Health approach that can be adopted by countries to reduce FLW while combating the spread of AMR and preventing diseases in food animals. However, the potential link between AMR and FLW is not discussed, as it is difficult to quantify due to a lack of data.

This consultation fell under two FAO Priority Programme Areas: One Health (for better production) and FLW (for better nutrition).

This expert consultative meeting enabled FAO to collect expert, science-based opinion on how AMR and animal disease contribute to FLW and on how to address the impact of FLW in terms of spreading animal disease and AMR in the environment.

Scope and objectives of the expert consultation

The objectives of this consultative meeting were:

- to collect expert opinion and generate scientific discussion on the impact of animal diseases and AMR on FLW;
- to determine the influence of FLW management (food waste disposal) on the transmission of AMR and pathogens; and
- using a One Health approach to identify measures and innovative practices that countries can adopt to reduce FLW, while combating the spread of AMR and preventing disease in food animals.

The expected meeting outputs were:

- mapping the impact of AMR and animal disease on FLW;
- profiling the contribution of FLW to the spread of AMR and pathogens;
- identifying gaps and needs to reduce FLW while combating animal disease and AMR; and
- recommendations of the consultative experts meeting.

The discussion focused on FLW of animal origin.

The expert consultation

Junxia Song introduced the meeting. Divine Njie reiterated FAO's global goals and core functions, presenting a general overview of FLW issues and FAO's strategic approach to dealing with them.

The expert consultation comprised two presentations, from Jonathan Rushton and Rungtip Chuanchuen. This was followed by general discussion. Participants were divided into two break-out rooms to discuss four questions (expected outputs). Ideas and comments were collected using notes on a Google Jamboard and from discussions. All participants attended the discussion in the plenary session. The meeting ended with Junxia Song's concluding remarks.

Jonathan Rushton presentation: "Livestock in society, AMU/AMR complex and food waste"

Jonathan Rushton described how food system transitions over the past 50 years have driven animal production, the price of animal-source food products and consumption, and how these transitions have impacted FLW and AMR issues.

For example, in a traditional food system in Bolivia, there was circularity between the two fields of production: maize and pigs. Maize surpluses could be used to feed pigs, and pigs could be sold for meat. There was a balance between the production of meat and grain, with the supply of and demand for grain limiting meat consumption. In this system, waste (from crops) was minimized and utilized to feed animals. AMR was not a big issue, as antimicrobials were not used. However, public health issues resulting from pathogens and parasites were probably extremely high.

The global food system has been driven by several "revolutions" that probably contributed to FLW and AMR. First, the "green revolution" in crop production stepped up significantly after the Second World War (due to innovations in genetics, irrigation, fertilizers, pesticides and so on). Then, in the 1970s, the oil-crop revolution (which saw the production of cooking oils) dramatically transformed the food industry, animal feeding and nutrition. The increase in crop area and the associated rise in crop and oil production had a large ecological footprint.

It also led to the "livestock revolution", which saw increases in livestock and meat production. It changed the way animals were fed and raised, and how they were processed. Production moved from grass-fed meat to grain-fed meat in one generation. It reduced animals' access to soil, decreasing the risk of parasite transmission. But intensive animal farming also requires high levels of animal health, and intensive AMU introduced AMR issues to the food chain. It also outlawed the feeding of food waste to animals, potentially leading to more waste. The efficiency of supply has driven down food prices in many societies and reduced the relative cost of meat, milk and eggs. The global meat supply has almost tripled in 60 years.

Jonathan Rushton suggested that the intensification of animal production and low meat prices had led to both higher food waste (due to the lack of circularity) and AMR issues. Food products could be contaminated by AMR (pathogens and/or residues), in which case they would be considered loss or waste. Food waste puts pressure on the economy (with a loss of energy and benefits), on social welfare, on food security (as resources that could have been used to feed people are wasted) and on the environment (an avoidable carbon footprint and GHG emissions from rotting landfill).

Lastly, food waste from animal products also means that more antimicrobials than needed have been used, increasing the likelihood of AMR.

The presentation ended with some critical observations:

- Better data capture and analysis to examine the burden of animal diseases and their control is strongly needed to estimate the economic impacts of food waste and AMR.
- Reconsideration of the use of food waste: In the past, the pig has been an asset in recycling waste into useful meat. More research on feeding food waste within the animal health regulatory framework is urgently needed to reduce the impact of FLW on the environment, as well as AMR impacts.

Rungtip Chuanchuen presentation: "AMR and food loss and waste"

Rungtip Chuanchuen started her presentation by setting out clear definitions of antimicrobials, resistance mechanisms and how they appear in food value chains. According to FAO, AMR "is the inherited or acquired characteristic of microorganisms to survive or proliferate in concentrations of an antimicrobial that would otherwise kill or inhibit them" (FAO, 2021).

She noted that bacterial AMR is not a new issue. The main driver of AMR is the misuse and overuse of antimicrobials. Antimicrobials are used, for example, in humans and food animals. In human health, they are used to kill or inhibit harmful bacteria that cause infection and disease. In animals, they are used to:

- treat sick animals – therapeutic use;
- control disease in a group of animals when some animals are sick – metaphylaxis;
- prevent disease in animals that are at risk of becoming sick – prophylaxis; and
- supplement animal feed in subtherapeutic concentrations – growth promotion.

A key issue is that important antimicrobials used for humans are also widely used in animals, increasing the risk of AMR.

AMR is a One Health issue because of the complexity of exposure and transmission pathways between humans, animals, plants and the environment.

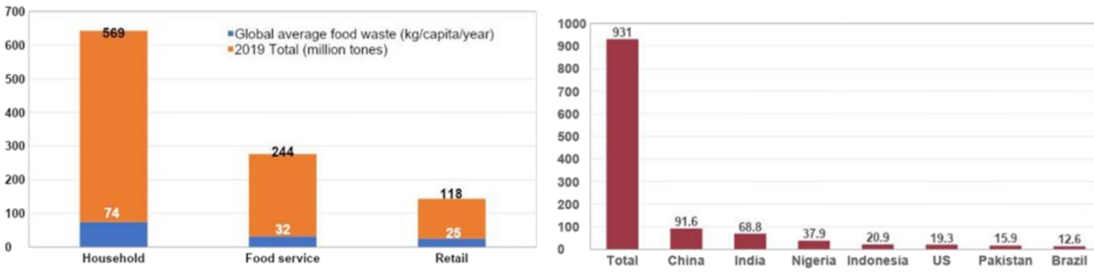
AMR can be a foodborne hazard, primarily introduced into the food production chain – preharvest, harvest and postharvest – in the following ways:

- pre-slaughter (or preharvest): AMU, contamination;
- slaughter/harvest: carry-over and cross-contamination; and
- post-slaughtering/harvest: carry-over and cross-contamination (also affected by AMU in preharvest) and AMU as a preservative.

The identification of pathogens and AMR at different steps in the food chain will lead to loss and waste.

Households are a main source of food waste. According to the UNEP Food Waste Index Report 2021, a total of 931 million tones of waste per year were generated by households, food service and retail, of which more than 60 percent was household waste (UNEP, 2021). In descending order, household waste was highest in China, India, Nigeria, Indonesia, the United States, Pakistan and Brazil. In 2019, Nigeria had the highest food waste per person per year.

Figure 2: Global estimates of food waste by sector (left) and estimated household food waste by country (right)



Source UNEP. 2021. *Food Waste Index Report 2021*. Nairobi. https://www.unep.org/resources/report/unep-food-waste-index-report-2021

A limited number of studies have attempted to understand the relationship between AMR/AMU and FLW. Ms Chuanchuen presented the results of three such studies, all of which followed AMR – bacteria and mobile genetic elements (MGEs) – in food waste, mostly compost.

1. In the United Kingdom of Great Britain and Northern Ireland, ten food waste samples from a site visit to one municipal compost facility showed significant bacterial population resistance to six selected antibiotic classes (Table 1) (Furukawa, Misawa and Moore, 2018). This underscores the fact that food waste carries resistant bacteria species.

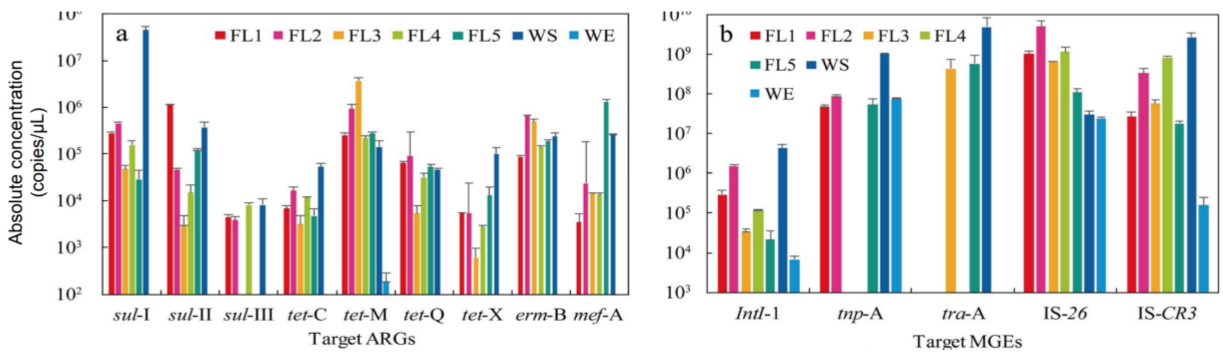
Table 1: Total antibiotic susceptibility test results for food waste compost samples (n=10)

Compost ID	Florfenicol	Antimicrobial Susceptibility Testing				
		Direct Ciprofloxacin	Tobramycin	Lincomycin	Minocyline	Amoxycillin
Sample1	S	S	R	R	S	R
Sample2	S	S	S	R	R	R
Sample3	S	R	R	R	R	R
Sample4	S	R	R	S	S	S
Sample5	R	R	R	R	R	R
Sample6	S	S	R	R	R	R
Sample7	R	S	R	R	R	S
Sample8	S	S	S	R	S	S
Sample9	S	S	R	R	S	S
Sample10	S	S	S	R	R	R

Source: Furukawa, M., Misawa, N. & Moore, J.E. 2018. Recycling of domestic food waste: Does food waste composting carry risk from total antimicrobial resistance (AMR)? *British Food Journal*, 120(11): 2710–2715. https://doi.org/10.1108/BFJ-12-2017-0701/FULL/XML.

2. Another study quantified AMR genes and MGEs at seven sampling points during food waste treatment processes at a disposal facility in China in April 2016. It demonstrated a high quantity of AMR genes and MGEs, re-emphasizing how food waste can be a reservoir of AMR genes and MGEs (Figure 3) (He *et al.*, 2019).

Figure 3: Concentration of AMR genes and MGEs in restaurant food waste leachates of different food waste treatment processes



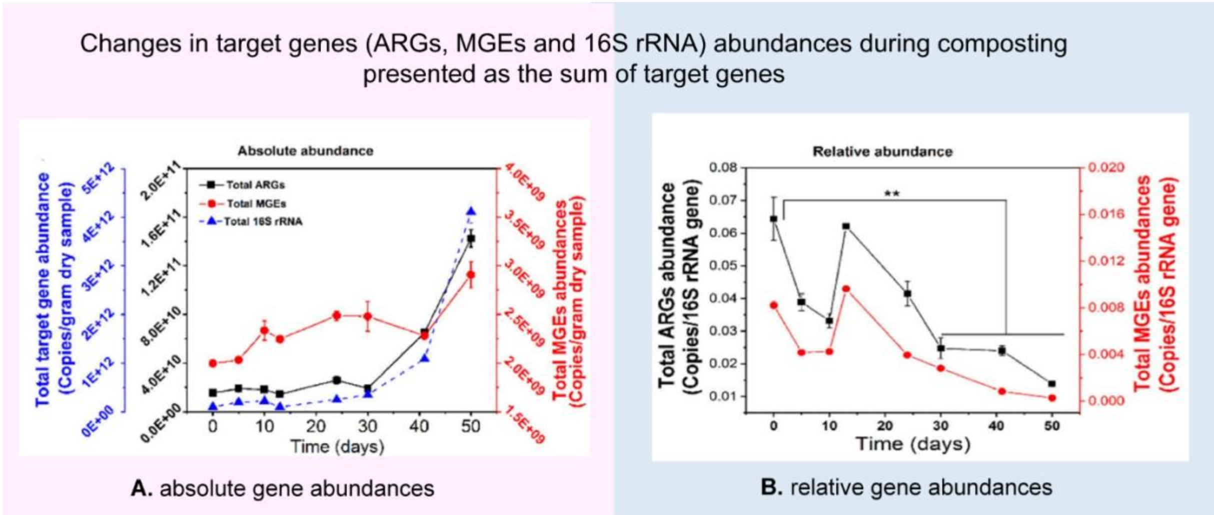
A. Concentrations of AMR genes B. Concentrations of MGEs

Note: Liquid-like food waste leachate (FL1) from the receiving hopper, centrifuged liquid-like food waste leachate (FL2), organic liquid (FL3) after separation of organic slurry, water-like liquid (FL4) after separation of mixed FL2, FL3 and waste oil, biogas slurry (FL5) after anaerobic digestion, excess sludge (WS) in the waste water treatment plant (WWTP) secondary sedimentation pool, and WWTP effluent (WE).

Source: He, P., Yu, Z., Shao, L., Zhou, Y. and Lü, F. 2019. Fate of antibiotics and antibiotic resistance genes in a full-scale restaurant food waste treatment plant: Implications of the roles beyond heavy metals and mobile genetic elements. *Journal of Environmental Sciences (China)*, 85: 17–34. https://doi.org/10.1016/j.jes.2019.04.004.

3. The third study analysed the target AMR genes – antibiotic resistant genes (ARGs), MGEs and 16S ribosomal RNA (16S rRNA) – by time of composting within 50 days, using eight samples at a full-scale aerobic composting plant in China. During the composting period, all targeted ARGs and MGEs were detected in every sample and were found to be increasing (Figure 3), demonstrating that traditional or common food waste compost may remain a reservoir of ARGs and MGEs and is not efficient means of removing them from food waste. Changes in ARGs were linked to shifts in the composition of bacterial communities. They are likely driven by the horizontal transfer of AMR genes and physicochemical composting properties (Liao *et al.*, 2019). Those data suggested that traditional composting might not be efficient at removing ARGs and MGEs from food waste.

Figure 4: Horizontal transfer of AMR genes and bacterial community composition shift during food waste composting



A. absolute gene abundances
B. relative gene abundances

Source: Adapted by Rungtip Chuanchuen from Liao, H., Friman, V.P., Geisen, S., Zhao, Q., Cui, P., Lü, X., Chen, Z. *et al.* 2019. Horizontal gene transfer and shifts in linked bacterial community composition are associated with maintenance of antibiotic resistance genes during food waste composting. *Science of the Total Environment*, 660: 841–850. https://doi.org/10.1016/j.scitotenv.2018.12.353.

An important take-home message was that once AMR gets into the food system, waste could become a reservoir, so it is best to prevent the introduction of AMR to the food system. Control points of AMR in food production include:

Preharvest (to reduce potential risk at harvest and at postharvest level)

- monitoring AMR/AMU – medically important antimicrobials (MIA) for human medicine, the World Organisation for Animal Health list of veterinary importance, WHO guidelines on the use of MIA in food-producing animals;
- improve awareness of the risk factors for or emergence and spread of AMR;
- control the availability of MIA;
- encourage responsible and prudent AMU;
- promote infection prevention and control;
- better biosecurity, and animal health and welfare;
- alternatives to antibiotics; and
- research innovations.

Postharvest

- monitoring AMR;
- effective treatment of food waste;
- adequate heat treatments and strict regulations on using food waste for feed;
- effectively enforce food waste legislation; and
- research innovation.

Rungtip Chuanchuen noted the lack of data and evidence on AMU in food production, as well as AMR and AMU on FLW. She concluded her presentation by citing research gaps that needed to be addressed as a priority in order to understand the AMR risk associated with FLW and what is needed to reduce it:

- the components of food waste that are the main sources of AMR;
- the fate of antimicrobials in food waste;
- AMR genetic elements in food waste;
- the dynamics of viable AMR bacteria in food waste;
- efficient technology to reduce AMR and bacteria in food waste; and
- guidelines for the disposal of AMR-containing food waste.

General discussion and break-out rooms

The discussion was organized into four main outputs.

1. The economic impact of AMR and animal disease on food loss and waste

Experts identified and listed some of the potential economic impacts of pathogens and AMR on FLW in animal production:

- loss of productive assets;
- cost to health systems (malnutrition and potential spread of microorganisms);
- impact on food security: higher food prices, malnutrition and poverty (loss of revenue);
- costs of energy and the environmental resources used for animal food production and loss: use of land, water, feed, labour and veterinary drug use;
- costs of waste management (environmental cost). Bovine meat is one of the highest contributors to FLW-associated GHG emissions. In addition, AMR may increase the cost of and need for specific treatment. There is a need to reconsider the use of food waste in a circular economy. Recycling food waste as animal feed (after treatment to avoid microbiological hazards such as pathogens and AMR) may contribute to the reduction of food waste by converting it into animal or aquatic feed. In addition, part of the energy for waste management could eventually be saved in a circular economy.

Participants bemoaned the considerable lack of data on the economic impact of AMR and animal diseases on FLW. However, some data may actually be available already. For example, meat is routinely tested for *Brucellosis* in an international trade context and contaminated produce is discarded. In which database these data reside is unclear, however. If the data exist, they are not accessible. For example, the private sector may possess certain data, but not release them for reasons of confidentiality.

The challenges as regards access to data differ according to the socioeconomic context. The data of big factories and retailers, especially in high-income countries, may be kept confidential by law. In low- and middle-income countries (LMICs), the issue may be more a lack of capacity to measure and produce such data. There is probably also a lot of waste due to specific technical difficulties (such as a lack of cold-chain integrity), but no data have been collected.

2. What is the contribution of food loss and waste to the spread of AMR and pathogens?

Experts expect the contribution of FLW to the spread of AMR and pathogens to be lower than that of other sources, such as preharvest waste (considered a production loss), manure and hospital sewage. However, the total volume of FLW also needs to be considered. More data are needed to undertake real comparisons between different sources of AMR.

In addition, the pathways of AMR spread and load may differ depending on the type of food waste. In authorized landfills, among the accumulation of debris and pollutants, antimicrobial residues may attract wild animals and be disseminated by the wind, rain and animals. What is more, the extent of discharge into nature is immeasurable. The impact of wild dumps may also lead to the accumulation and attraction of certain pests, risking the dissemination of pathogens and AMR by those species, making the spread even more difficult to monitor. However, participants again stressed the lack of primary data on the specific contribution of different types of food waste to the spread of AMR and pathogens.

Those remarks reinforce the presentation of Rungtip Chuanchuen, who presented the studies showing that ARGs, MGEs and antimicrobial-resistant bacteria were to be found in food waste treatment processes and that AMR persists to a certain extent, despite food waste treatments, confirming that food waste is a realistic pathway for the spread of AMR in the environment.

3. Identifying gaps and needs to reduce food loss and waste while combating animal disease and antimicrobial resistance

Although AMR can be a foodborne hazard that results in FLW, there is very limited evidence on the direct relationship between FLW and AMR/AMU and, hence, the research needed to reduce the impact of AMR/AMU on FLW.

One of the main gaps identified in the consultation was the lack of data on FLW relative to AMR for further evidence-based actions. Measuring economic impacts and assessing the risk associated with AMR and FLW relies on a deep understanding of the value chains and identification of the infrastructures for generating, collecting and analysing data on:

- The level and type of contamination (antimicrobial residues, pathogens). Organic production may reduce levels of AMR and require less AMU.
- Volume and type of food waste. Volumes produced in regulated areas may be measured, unlike discharges outside these areas (slums, tourism and so on). Marine pollution is also largely underestimated (shipwrecks, loss of fishing gear, deliberate or accidental discharge) and is rarely visible (depth). Evaluation of the quantities of waste collected during tides or important climatic phenomena would allow us to evaluate the impact of pollution on the environment.
- Destination and treatment of waste. For example, collectors of food waste from various destinations create a final product (animal feed) that contains a mixture of multiple pathogens and transmits it over long distances.
- Consider specific LMIC settings when it comes to waste treatment. For example, the treatment of carcasses condemned in abattoirs due to disease/lesions and drug residues, along with their effects on spreading pathogens and AMR, may differ greatly based on a country’s infrastructure.

- Evaluate the risk associated with human and animal health. Risk assessments are needed on the impact of AMR transmitted from food waste to the environment, as well as from farms to human and animal health. The impact of the spread of AMR in wildlife is also unknown.

Research priorities for addressing the risk associated with AMR (both resistant bacteria and antimicrobial residues) spreading through FLW include:

- identifying and preventing the presence of pathogens and antibiotic residues in the food value chain;
- understanding the fate of ARGs and AMR bacteria in the different food waste treatment processes;
- efficient technology to reduce AMR bacteria and determinants in food waste; and
- guidelines for the disposal of AMR-containing food waste

4. Recommendations for reducing food loss and waste while combating animal disease and antimicrobial resistance

Immediate actions to fill the information gaps were proposed during the consultation:

- a mapping exercise of the potential fate of AMR-contaminated FLW and an evaluation of the potential risks within a One Health context for the environment, animals and humans;
- the fate of antibiotics and ARGs in different food waste treatments;
- an assessment of the state of knowledge on interconnections between FLW and AMR through a literature review;
- capacity development to collect or produce data on FLW contamination by AMR;
- awareness raising through communities of practice; communication of risks to all actors involved; prevention in the event of endangerment of the environment or the introduction of disease;
- resource mobilization to enable engagement in the aforementioned actions;
- exploration of opportunities for innovative solutions and businesses in FLW and AMR;
- exploration of public-private partnership models;
- promotion of research or evaluation tools following the One Health approach in reducing FLW;
- more research on the impact of AMR from the environment and farms on human health and AMR from human contact with food (for example, farm workers) through epidemiological studies;
- risk assessment of food waste/losses on the incursion and spread of animal diseases and incorporation of the results into the disease investigation process;
- building on preventive health interventions to combat animal diseases and, therefore, contribute to both the reduction of loss in food animals due to disease and the reduction of antibiotic use;
- a strengthening of surveillance and control systems and the generation of unified information systems for agricultural health, food safety, and environmental and human health.

In the long term, efforts should lead to guidelines on the disposal of FLW with regard to AMR and animal pathogens.

Conclusions

FLW and AMR are major agrifood system issues and, until now, have been addressed independently. The first key conclusion of the expert consultation is that the probability of interconnections between FLW and AMR is high and deserves more attention. In the livestock sector, AMR and animal diseases are probably contributing to FLW. On the flip side, based on a few preliminary studies, FLW may contain antibiotic residues, ARGs and AMR bacteria and thus contribute to the spread of animal diseases and AMR in the environment. Awareness raising on FLW–AMR interconnections is needed.

The second conclusion is that there is a major lack of data on AMR in the context of FLW. Some may exist in the private sector, but is difficult to access for confidentiality reasons. However, primary data may be needed, particularly in an LMIC context. Data at different points of the food chain are needed to address the following questions:

- Where and how often does AMR contamination occur in the food chain?
- What components of food waste are the main sources of AMR?
- What is the fate of antimicrobials in various food waste management processes?
- What is the impact of various food waste treatments on AMR?

Resources will be needed to collect and produce these data.

Together, these data will allow us to better understand AMR risks related to food waste and evaluate the economic impact of AMR on FLW. Evidence-based measures and innovative practices can be adopted by countries in a One Health approach to reduce FLW, while combating the spread of AMR and preventing disease in food animals.

References

FAO. 2013. *Food wastage footprint – Impacts on natural resources*. Rome. https://www.fao.org/3/i3347e/i3347e.pdf

FAO. 2021. *The FAO Action Plan on Antimicrobial Resistance 2021–2025.* Rome. https://doi.org/10.4060/cb5545en

FAO. 2022. *Voluntary code of conduct for food loss and waste reduction*. Rome. https://doi.org/10.4060/cb9433en

FAO, IFAD, UNICEF, WFP & WHO. 2022. *The State of Food Security and Nutrition in the World 2022*. Rome, FAO. https://doi.org/10.4060/cc0639en

FAO, UNEP, WHO and WOAH. (2021). Joint Tripartite (FAO, OIE, WHO) and UNEP Statement. *Tripartite and UNEP support OHHLEP's definition of "One Health"*. Rome. https://www.fao.org/3/cb7869en/cb7869en.pdf

Furukawa, M., Misawa, N. & Moore, J.E. 2018. Recycling of domestic food waste: Does food waste composting carry risk from total antimicrobial resistance (AMR)? *British Food Journal*, 120(11): 2710–2715. https://doi.org/10.1108/BFJ-12-2017-0701/FULL/XML

He, P., Yu, Z., Shao, L., Zhou, Y. & Lü, F. 2019. Fate of antibiotics and antibiotic resistance genes in a full-scale restaurant food waste treatment plant: Implications of the roles beyond heavy metals and mobile genetic elements. *Journal of Environmental Sciences (China)*, 85: 17–34. https://doi.org/10.1016/j.jes.2019.04.004

Liao, H., Friman, V.P., Geisen, S., Zhao, Q., Cui, P., Lu, X., Chen, Z. *et al.* 2019. Horizontal gene transfer and shifts in linked bacterial community composition are associated with maintenance of antibiotic resistance genes during food waste composting. *Science of the Total Environment*, 660: 841–850. https://doi.org/10.1016/j.scitotenv.2018.12.353

Lipinski, B. 2020. Why does animal-based food loss and waste matter? *Animal Frontiers*, 10(4): 48–52. https://doi.org/10.1093/af/vfaa039

United Nations Environment Programme (UNEP). 2021. *Food Waste Index Report 2021*. Nairobi. https://www.unep.org/resources/report/unep-food-waste-index-report-2021

Annex 1 - Meeting agenda

<table>
<tr><td>14.00-
14.05</td><td>Opening remarks</td><td>Junxia Song

Senior Animal Health Officer
Joint Zoonotic Diseases and AMR Centre (CJWZ)
Food and Agriculture Organization of the United Nations (FAO)</td></tr>
<tr><td>14.05-
14:25</td><td>General overview</td><td>Divine Njie (ESF)

Deputy Director
Food Systems and Food Safety (ESF)
Food and Agriculture Organization of the United Nations (FAO)</td></tr>
<tr><td>14.25-
14.45</td><td>Keynote speaker 1</td><td>Johnathan Rushton

Professor of Animal Health and Food Systems Economics, Institute of Infection, Veterinary and Ecological Sciences, University of Liverpool</td></tr>
<tr><td>14.45-
14.55</td><td colspan="2">Q and A</td></tr>
<tr><td>14.55-
15.15</td><td>Keynote speaker 2</td><td>Rungtip Chuanchuen

Head, Research Unit in Microbial Food Safety and Antimicrobial Resistance Director, Center for Antimicrobial Resistance Monitoring in Foodborne Pathogens (in cooperation with WHO)
Director, Global Foodborne Infections Network: South-East Asia and Western Pacific Region
Department of Veterinary Public Health
Faculty of Veterinary Science, Chulalongkorn University, Thailand</td></tr>
<tr><td>15.15-
15.30</td><td colspan="2">Q and A</td></tr>
<tr><td>15.30-
15.50</td><td colspan="2">Break-out rooms:
Food loss and waste and antimicrobial residues and transboundary animal diseases</td></tr>
<tr><td>15.50-
16.25</td><td colspan="2">Plenary discussion</td></tr>
<tr><td>16.25-
16.30</td><td colspan="2">Conclusions</td></tr>
</table>

Annex 2 – FAO Voluntary Code of Conduct to reduce food loss and waste

The FAO Voluntary Code of Conduct for Food Loss and Waste Reduction has specific articles on the reduction of FLW in the context of animal diseases and AMR (FAO, 2022):

- Article 4.8 encourages governments to structure and implement public policy frameworks to ensure safety and quality of reused and/or recycled byproducts and inedible parts of the food supply chain. If that surplus cannot be reused or redirected, waste disposal procedures should be explicit.
- Articles 5.3 to 5.5 cover the many ways to avoid food loss by preventing animal diseases and crop deterioration. While mentioning the need for good pest and disease management, article 5.3 specifically states the need to “use antimicrobials in a prudent and responsible manner in order to reduce antimicrobial resistance”.