**Supplementary material**

**Opinion paper: Food loss and waste to animal feed**

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**Background and Introduction**

A huge amount of food (1.3-1.6 G tonnes) get wasted globally every year, which is estimated to have enormous environmental (ca 3.3 G tonnes of CO2 eq. greenhouse gas emission/year, 305 km3 water/year, 1.5 billion ha land to grow food that is wasted), social (936 billion US$) and economic (1055 billion US$) costs (FAO 2014a). The global methane emission from landfills due to food waste was third largest anthropogenic source of methane (next to enteric fermentation and fossil fuel burning), estimated as 11% of global methane emission or nearly 799 million metric tonnes CO2 equivalent in 2010 (EPA, 2011). The food loss and waste (FLW) also has an impact on food security and on local and national economies. A part of these losses can be converted to animal feed, without compromising animal product safety and animal and human welfare. Similarly a large amount of non-food parts of crops (NFPC) such as crop residues and agro-industrial by-products originate from the food supply chain. These also require natural resources to produce and have economic and environmental costs associated with them. Wasting and burning of non-food parts of crops release greenhouse gases and can cause animal and human health concerns. The FLW and NFPC are valuable animal feed resources and can be brought back to food chain by using them as a part of animal feed, after ensuring that animal health and welfare and animal product safety and quality are not compromised and that legislative requirements are met.

There are projections that between 60 to 70% more animal products would be consumed in 2050 than consumed currently (FAO 2011), resulting in increased requirement of animal feed. Meeting the future feed requirement is a big challenge given the scenarios of increase in land degradation, food-fuel-feed competition, water deprivation and on-going climate change. Currently 33-35% (approx. 790 million tonnes) and 5-6% (approx. 143 million tonnes) of grains are used annually for animal feeding and biofuel production respectively (FAO 2012, 2015a). The better use of FLWe and NFPC as feed resources, would also decrease food-feed-fuel competition and enlarge the feed resource base, contributing to feed and food security. In addition, their use is expected to decrease carbon- and water-footprints of animal products.

FAO organized an electronic conference on ‘Utilization of Food Loss and Waste as well as Non-Food Parts as Livestock Feed’, from 1 October to 30 October 2015, aiming to understand better the definition of FLW in relation to use of foods as animal feed and the conversion of such wastes to animal feeds. The approach used for conducting the e-conference and the roles of various stakeholders are presented here. The former would enable better appreciation of the opinions expressed with regard to the FLW definition in the opinion paper, and the latter would help expand and initiate a debate on the roles of various stakeholders in food-feed value chain including policy makers for efficient and safe use of FLW and NFPC as animal feed.

**Approach used for the e-conference**

A large number of subscribers (630) and 254 messages that were received from 123 participants from 47 countries shows considerable interest of various stakeholders in the conference proceedings. To set the scope and scene for the conference a background document with information on a framework on ‘Food Loss and Waste plus Non-Food Part to Livestock Feed’ was developed (FAO, 2015b). This framework was built on the ‘Food loss and waste framework of FAO’ (FAO, 2014a) and the ‘Definitional framework of food loss’ (FAO 2014b). The framework was prepared as a key step towards improving our understanding of the FLW ‘hotspots’ (the points at which the losses and waste are substantial) as well as non-food parts in the food supply chain that could possibly be channeled to animal feed; thereby, furthering resource use efficiency and food security. Also this framework formed the basis for setting up leading questions for the participants to get their inputs. The leading questions for the first week were about the definition of FLW related to feed and an inventory of plant resources used for food and/or feed. The issues of feed safety and technologies to utilize FLW as animal feed including the roles of the food industry and the feed manufacturing industry were discussed in the second week. While the third week discussions focused on the roles of researchers, Non-Governmental Organizations (NGOs), civil societies, farmers and policy makers in making use of FLW and non-food parts of crops as feed.

**The role of various stakeholders**

The food industry and the feed manufacturing industry both play an important role in developing feed processing technologies that will process food lost and wasted and non-food parts of crops (NFPC) into livestock feed that is safe. The food industry should consider food wastes and losses as a value added product, not a “waste” *per se* by prioritising the recycling of FLW as animal feed over alternatives such as composting, anaerobic digestion, or land filling, which all have an environmental burden. The food industry holds an important responsibility to maintain safety and integrity of former foodstuffs destined for animal feed use, by storing such products in good condition. The food industry plays a key role in ensuring the application of the best circular solution to its FLW.

Research and researchers play a very important role in promoting safe and efficient utilization of FLW and NFPC as feed. The role of researchers could be to: a) identify, describe and quantify residues that could be available in different value chains in their countries or in the region where they develop their research; b) analyze its chemical composition: nutrients and xenobiotics, and ensure feed safety; c) evaluate different treatments/processes for conservation and value addition; d) evaluate animal feeding behavior and feeding response; e) investigate effect (smell, taste, fatty acid composition, palatability, etc.) on fresh or processed food products (milk, meat, eggs); f) publish information in different formats (research paper, technical information, media articles, etc.); and g) train professionals, consultants and producers.

While in several countries significant research has already been done for better utilization and development of technologies for NFPC this was less so for food waste. However, the adoption of these technologies is generally very limited and there is a need to ensure that research is done in such a way that it results in development of market-oriented technology, practice or processes based on locally available biomass. Also building of a business model around feeding technologies and their implementation using public-private partnerships or through improving organizational and institutional frameworks and infrastructure helps in large scale adoption of feeding technologies (Makkar, 2017). Applied research, gaining of knowledge or understanding to convert ideas into operational businesses often remains unattended or neglected in developing countries. Research is often performed in isolation that seldom finds adoption by farmers or industry. Multidisciplinary teams are important to address technical, social and economic aspects of the issues. There is a need for solutions or technologies that are not only technically sound and economically beneficial but also socially acceptable/adaptable (Makkar, 2016) and that there may be several aspects other than technical such as environmental, legislative, economic, and social (in case of diverting food losses to animal feed) that need to be addressed. Investment of the private sector in research and development would be important to establish linkages between the different stakeholders of feed development.

The role of NGOs and Civil Societies largely as interlocutors between research and the potential creators or users of FLW and of NFPC, mainly with the focus on livestock owners or farmers. Their role could be to educate people to reduce potential FLW through extension works and get involved in collection and distribution of material and in demonstrations and awareness programmes for farmers and the public. The prevention of unnecessary crop losses is an important way to increase the availability of resources, both for food and feed. This could be achieved through modern harvesting technologies, better post-harvest management and reduction of losses during processing and distribution. There is scope of processing for improved utilization. Several experiments have been conducted and several methods have been suggested to utilize NFPC for ruminants but could not be implemented at small scale, except for chaffing, soaking, ‘Total Mixed Rations (TMR)’, feed blocks and supplementation of green (success and failures reference). Also NGOs and Civil Societies could have a constructing role in assisting the government to make appropriate laws. In addition, they may play an important role in creation of infrastructures, provision of basic farm inputs, and conducting feasibility evaluation for example on transporting food wastes and non-food parts from areas of production to areas of utilization, as well as raising awareness to minimize environmental pollution by using food loss and waste or former foodstuffs as feed for food-producing animals. It may be argued that in some regions the activities of NGOs and Civil Societies for promoting use of food waste and loss as animal feed may get in conflict with the existing feed safety regulations. Appropriate mechanisms to prevent this may be needed.

The farmers have a great wealth of knowledge on how to utilize NFPC and food co-products for livestock feeding. That needs tapping. On the other hand, for feed resources originating from emerging FLW and NFPC, the farmers’ knowledge and skill would need to be improved for efficient use of such feed resources. From an environmental point of view farmers could be rewarded/recognized if they manage losses and waste in an environmental friendly way and could through "demonstrator farms" become an example of what and how things should be done.

The important role of policy makers could be development of frameworks that reduce FLW and encourage the appropriate utilization of co-products from the food industry and NFPC as animal feed. There is a need for policy guidelines, legislation, regulations and national standards that facilitate the reduction of FLW and allow for a safe use of FLW as animal feed including the promotion of the HACCP approach for those ingredients that are brought by suppliers on the market. Legislation should also ensure that food losses/wastes are processed for feed at production site to minimize environmental pollution (as in breweries and in food processing industries that produce e.g. citrus and tomato pulp, apple pomace, among others). Legislations for ensuring quality and for assisting farmers with insurance schemes that can protect them from losses due to natural disasters are also required. Development of policies that sees food-feed industries as an integral part of the circular economy would help to promote the use of non-food parts as animal feed, giving triple-wins.

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