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Pet Food as the Most Concrete Strategy for Using Food Waste as Feedstuff within the European Context: A Feasibility Study

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Abstract: Food loss and waste have a negative environmental impact due to the water, land, energy and other natural resources used to produce the wasted food, along with post-consumption disposal costs. Reducing food waste will thus help improve sustainability and decrease the environmental impact of the food system. Using food waste for animal feed is of growing importance in terms of the policies targeted at tackling food waste but the current legal framework in the European Union (EU) strongly restricts the possibility of using food waste for this purpose. The aim of this work is to evaluate the feasibility of innovative measures for feed production in the EU and to identify the best strategies to implement them. First, a technical evaluation of a case study is presented, which is a process developed in the United States for urban food waste transformation into animal feed. Second, there is an analysis of the potential application of this process in the European Union within the current legal framework. The results reveal that the feed product derived from food waste is compliant with EU safety requirements and is nutritionally valuable. This work also suggests that the implementation of this kind of process in the European Union has great potential, provided that food surplus is recovered and treated before it turns into waste and that the different types of food surplus identified are used as feed for the right animal type in accordance with European legislation (i.e., livestock, aquarium fish, pets). On these terms, pet food can be the most concrete strategy for using food waste within the European context. In general, the implementation of feed-from-food measures to reduce food waste in Europe is already possible and does not need to wait for further policy interventions.

Keywords: food waste; animal feed; food waste re-use; sustainability

1. Introduction

Promoting environmental, economic and social sustainability is the real challenge that agri-food systems are faced with, and food waste is certainly one of the most complex and important problems in developed countries. Studies commissioned by the Food and Agriculture Organization (FAO) in 2015 found that one-third of food produced for human consumption is lost or wasted globally [1]. More specifically, the quantification of food waste production in the United States was estimated at 66 million tons in 2010 which was selected as the baseline for national food loss, and a target of a 50% reduction in the waste program by 2030 was set. In the European Union, 88 million tons of food are wasted annually in the EU, 70% of which come from households, food services and retail sectors, and the remaining 30% come from the production and processing sectors [2]. However, the different interpretations of the concept of food waste makes the global food waste issue difficult to define conclusively [3] and recent studies highlight the importance of measuring the quantity and value of food waste accurately [4,5]. Nevertheless, the basis for a correct measurement is the distinction between the terms food surplus and food waste: In this article, the term "food surplus" refers to food produced beyond our nutritional needs, whereas waste is whatever is produced in the food system that ends up in the landfill [4,6].

Due to the magnitude of the related ethical and economic issues, the scientific literature has increasingly focused on the impact of waste treatment strategies [7–12].

There are multiple ways of decreasing the generation of waste, and despite the fact that there are differences in national policies among EU and US Countries, their common pillar is the prioritization of food waste prevention. Strategies for better production, such as planning and resource use, improving preservation and packing technologies, and transportation and logistics management are implemented for this purpose [1]. Prevention includes supplementary actions such as the redistribution of food surpluses to people for charitable purposes: The guidelines for a common European food waste policy (FUSIONs) foster a policy environment focused on social innovation initiatives to promote food redistribution and cooperation with the actors in the food supply chain. One example of this is an EU-wide program that encourages food business operators to distribute their unsold edible food to charities. Although food redistribution strategies can provide both pro-social and pro-environmental gains due to their concern to reduce food surplus and food insecurity [13], several studies have shown that they offer a limited contribution to food waste prevention [14,15].

Finally, the re-use of food for animal feed can be included as part of the prevention strategies such as the last chance to use food and its nutritional properties before it turns into waste, and thus treated through anaerobic digestion, composting, incineration or landfill. Several studies demonstrate that food waste-derived feed is an adequate alternative when properly supplemented [16,17] and a number of East Asian states have in the last 20 years introduced systems for the safe recycling of food waste into animal feed [18].

Converting food waste into animal feed is also a sustainable practice compared to the environmental and health impacts of different technologies for food waste processing, including anaerobic digestion and composting [19]. The authors found that feed production from food waste has the lowest impact and is thus capable of providing environmental and public health benefits at a societal level.

Given this potential, it is clear that the reuse of food for feed purposes needs to be more extensively explored and evaluated. Although fostering the use of (former) foodstuffs and by-products for feed production is part of the recommendation released by the EU Fusion project, to date these practices are hardly implemented in the European Union due to the current legal framework on food waste management and livestock feeding. Several authors have highlighted this lack of practice and proposed to introduce policy changes, together with consumer and industry support, in order to re-introduce the possibility of using food waste as livestock feed in the European Union [18–22].

The aim of the study is to evaluate the feasibility of innovative measures for feed production in the EU and to identify the best strategies to implement them. Starting from an analysis of an innovative food waste treatment for feed production developed in the US (nutritional properties and safety), the present study provides an evaluation of its potential applicability in the European Union, given the current legal framework in force. The study also suggests strategies to implement similar technologies within the European framework on food waste use.

2. Methodology

In evaluating the potential application of new feed-from-food-based strategies, which have, as of yet, never been implemented in the European Union, a food waste treatment operating in the US was considered as a case study. The methodology used is composed of two main steps: an analysis of the case study in order to evaluate the characteristics of the final product (feed) obtained and, in a second stage, an assessment of the applicability of such a treatment within the European legal framework.

2.1. Definition of the Flow Process

The survey was carried out from January 2016 to January 2017, during which the data were collected from a specific transformation technology located in the USA that receives food waste through controlled flows and procedures from commercial and residential locations in order to produce secondary food products for animal feed (supplementary information in Section SA). The facility is powered daily through the collection of commercial and residential food scraps in coordination with several urban centers and institutions, including: City of Santa Clara, Stanford University, City of San Jose and the City of Sunnyvale. The daily amount of urban food waste collection is of 50 tons/die on average.

Figure 1 shows the steps of a system for processing primary food product waste into a secondary food product.

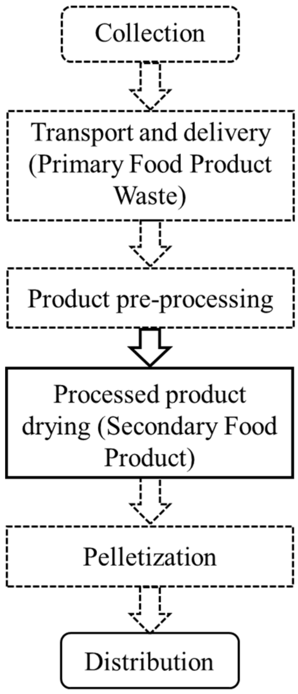


Figure 1. Flow chart of the system.

2.2. Characterization of Secondary Food Product

The secondary food product was evaluated in terms of the EU sanitary requirements to understand whether this product could be included in an animal feed formulation. From January 2016 to January 2017, the secondary food product sampling took place once every two months. On each collection day, three batches of secondary food product with a mass of 2–3 kg were randomly selected in order to obtain a complete safety and nutritional assessment of the product. All study parameters regarding the secondary food product derived from the process were determined by identifying the EU hygiene requirements for pet food, which was regulated by the Directive 2002/32/EC of the European Parliament and the Council on 7 May 2002 on undesirable substances in animal feed. The sampling and the analysis methods were carried out taking into account the Commission regulation (EC) No 152/2009 of 27 January 2009 which laid down the methods of sampling and analysis for the official control of feed. The undesirable substances studied were: nitrites, the presence and the level of contamination of mycotoxins pesticides, heavy metal and microbiological parameters (Table 1).

Table 1. Parameters for secondary food product evaluation.

Nitrites	Sodium Nitrite
Mycotoxins	Deoxynivalenol, fumonisin B1 and B2, aflatoxin B1 ochratoxin A and zearalenone.
Pesticides	Acephate, Azinphos ethyl, Azinphos methyl, bromophos methyl, Carbophenthio, Chlorfenvinphos, Chlorpyrifos ethyl, Chlorpyrifos methyl, Chlorthiophos, Coumaphos, Diazinon, Dichlorvos, Dimefox, Dimethoate, Ethion, Fenchlorphos, Fenitrothion, Fonofos, Phorate, Phosalone, Phosphamidon, Isofenphos, Malathion, Methamidophos, Methidathion, Mevinphos, Omethoate, Parathion ethyl, Parathion methyl, Pirimiphos Methyl, Profenofos, Quinalphos, Terbufos, Tetrachlorvinphos, Thionazin, Vamidothion.
Heavy metals	Pb, Cd, As and Hg.
Microbiological analyses	Mesophilic aerobic bacteria, enumeration of *Enterobacteriaceae*, enumeration of *E. coli*, enumeration of coagulase-positive staphylococci, *Bacillus cereus*, total coliform bacteria, sulphite-reducing Clostridia, *Clostridium perfringens*, detection of *Salmonella* spp., *Listeria monocytogenes*, staphylococcal enterotoxins, *E. coli* STEC, *Yersinia enterocolitica* and *Clostridium botulinum.*
Physical contaminants	Lithoid material (>5 mm), other inert materials such as glass and metal (<3.3 mm and 3.3 mm–10 mm), plastic material (<3.3 mm and 3.3–10 mm), plastic material and other inert materials (>10 mm), and glass metal and plastic (>2 mm).

Physical contaminants were studied in order to verify the efficiency of the identification pre-process and the separation of oversized and inorganic material in the secondary food product (Table 1). The secondary food product was evaluated in terms of its nutritional suitability as a raw material for animal feed, the nutritional parameters analyzed were: dry matter, crude protein, ether extract, crude fiber, ash, mineral content (Ca, P, K, Na, Mg, Fe, Zn, Mn, Cu and Cr), and fatty acid content.

2.3. Applicability in EU

Estimating the degree of technical applicability of innovative treatments that are able to produce animal feed, using food waste as input, need to take into account the specific food waste measures currently in force in the European Union. A systematic classification was thus carried out of the complex scenario of the regulations regarding (i) re-using food waste and the provisions for its reduction; and (ii) provisions for animal feed production in the European Union and its composition and safety requirements. Based on the analysis of the regulatory framework, a final evaluation of the applicability of the US case study considered was performed. In addition, the best strategies to improve the conversion of food waste into animal feed within the European Union were therefore suggested.

3. Results and Discussion

3.1. Definition of the Flow Process

3.1.1. Collection, Transport and Delivery—Primary Food Product Waste

The primary food product waste is collected on site and emptied into a special transport vehicle that keeps the waste product separate from the general environment, thus keeping odors to a minimum, minimizing the attraction of insects, rodents, and other vectors, and also to reduce the contamination of the primary food waste during transport.

3.1.2. Production Pre-Processing

At the time of delivery to the processing site, the primary food waste is pre-processed to produce an intermediate product (mash). The pre-processing subsystem is comprised of a magnetic and a screening subsystem for removing oversized and inorganic material, including ferromagnetic material, glass and plastic.

3.1.3. Processed Product Drying—Secondary Food Product

The mash is held in a tank and then transferred to the dryer through a progressive cavity pump. The dryer is configured to reduce the moisture content of the mash. The under vacuum condition lowers the effective boiling point within the dryer to remove the evaporated moisture safely below a temperature at which the primary food waste could burn or otherwise might overheat, thus minimizing emissions.

The water vapour can then be condensed into water which is then captured by the dryer, and can be used for various purposes, including cooling and cleaning sections of the dryer.

The dryer gradually dries the mash without exceeding 120 °C so that the nutrients are retained in the dried product.

3.1.4. Pelletization

The secondary food product is dried by the dryer to a 10–20% moisture content, then extruded and cut to generate a finished dried meal or a pellet. The temperatures and pressures created in the extrusion process allow for a high temperature and short time (HTST) process.

3.2. Characterization of Secondary Food Product

The analysis of the undesirable substances found in each batch of secondary food products showed that the nitrite levels were below 4 mg/kg, in accordance with the maximum EU legal limit of 15 mg/kg expected for raw materials for animal feed formulations (Table 2). The mycotoxin level in all batches was below the detection limit (<0.05 μg kg^{-1} wet weight). The results of the mycotoxins level of the secondary food product presented in this study are within the expected limits because the food waste collected in the US was mainly generated from food residues for human consumption (Table 2). Pesticide residues were not detected in any of the batches of the secondary food product, and thus the product appeared to be in line with the permitted EU limits. The heavy metals analyzed were found with the following concentrations: Pb (3.44 mg/kg ± 0.08), Cd (0.22 mg/kg ± 0.003), As (0.68 mg/kg ± 0.005) and Hg (under the detection limit of the analysis method <0.100 mg/kg), and all the results were well below the maximum permitted limits (Table 2).

Microbiological analyses showed that *Salmonella* spp. and *Listeria monocytogenes* were absent in 25 g of all analyzed batches thus conforming to the Reg. (EC) No. 2073/2005. In addition, the absence of Staphylococcal enterotoxins, *Bacillus cereus* enterotoxins, *E. coli* STEC, *Clostridium botulinum* and *Yersinia enterocolitica* and the presence below the detection limit of 1 log CFU/g of the hygiene process indicator microorganisms confirmed the compliance of the secondary food products with EU food and feed safety criteria. As confirmed by previous studies, heat treatment plays an important role in decreasing the pathogen population in several food matrices such as food scraps [23,24]. Physical contaminants were not detected in any of the batches of the analyzed secondary food product.

Table 2. Guide values in relation to feedstuff in the EU.

	Secondary Food Product	Maximum Level in EU [a]	EU Regulation	Specification
Nitrites	<4	15	2002/32/EC	Limits for complete feedstuff for pets
Deoxynivalenol,	below detection limit	Not available	2006/576/EC	
Fumonisin B1 + B2	below detection limit	5	2006/576/EC	
Aflatoxin B1	below detection limit	0.02	2002/32/EC	
Ochratoxin A	below detection limit	Not available	2006/576/EC	
Zearalenone	below detection limit	Not available	2006/576/EC	
Pb	3.44	5	2002/32/EC	Limits for complete feedstuff
Cd	0.22	2	2002/32/EC	Limits for complete feedstuff for pets
Total arsenic	0.68	6	2002/32/EC	Limits for complete feedstuff for fish and fur animals
Hg	below detection limit	0.4	2002/32/EC	Limits for complete feedstuff for pets

[a] Guide values in mg/kg (ppm) relative to feedstuff with a moisture content of 12%.

The results of the chemical composition, fatty acid and mineral content are shown in Tables 3–5, respectively. The data related to the nutrient composition of the secondary food products was highly variable. In fact, the variation in feed values of food waste depends on the origin of the waste and other social aspects such as the age profile, ethnic origin and dietary habits of householders [25–27].

Given that food waste reflects the human diet, the feed it is derived from is very often nutritionally balanced, with a good nutritional quality as shown by the nutrient analysis [28]. Some authors highlight that restaurant food waste is higher in fat and protein as found in the secondary food product analyzed in this study [29,30].

The high protein content in food waste responds to the necessity to find new protein sources, since Europe's capacity to produce protein feed is seriously inadequate to meet market demand [31]. According to Pond and Maner [32], one of the barriers to feeding animals with food waste is the variation in types and sources, which is reflected in the varied composition of the secondary food product. Further studies are thus necessary in order to standardize the raw materials derived from food waste transformation.

The fatty acid profile of secondary food product appears to be an interesting source of essential fatty acids, in terms of the omega 6 (26.3%) and omega 3 content (3.2%). In line with results, Myer, et al. [26] reported a similar fatty acid profile and indicated that the results depend on the mixture of animal and vegetable fat normally found in household and restaurant waste. Macro-minerals such as calcium, potassium, phosphorous, sodium and magnesium were found in all the batches analyzed, and the heterogeneity of food waste makes the secondary food product a good source not only of protein but also of minerals.

Table 3. Chemical composition of the secondary food product.

Parameters [a]		
Dry matter	Mean	87.07 ± 0.02
	Min	84.40
	Max	88.96
Crude protein	Mean	24.00 ± 0.02
	Min	19.61
	Max	27.10
Ether extract	Mean	7.94 ± 0.05
	Min	3.89
	Max	15.00
Crude fiber	Mean	16.62 ± 0.03
	Min	11.00
	Max	21.00
Ash	Mean	12.68 ± 0.02
	Min	9.95
	Max	12.00

[a] Data are reported as % on wet weight ± standard deviation.

Table 4. Fatty acid content in secondary food product.

Fatty Acid Content [a]	**(% of Total Fatty Acids)**
Saturated fatty acids (SFA)	37.42 ± 0.30
Monounsaturated fatty acids (MUFA)	33.28 ± 0.16
Polyunsaturated fatty acids (PUFA)	29.31 ± 0.13
Omega-3 fatty acids	3.28 ± 0.05
Omega-6 fatty acids	26.03 ± 0.08
C12:0 Lauric acid	0.94 ± 0.08
C14:0 Myristic acid	2.02 ± 0.04
C16:0 Palmitic acid	23.56 ± 0.11
C16:1 Palmitoleic acid	1.95 ± 0.47
C17:0 Margaric acid	0.31± 0.01
C17:1 Magroleic acid	0.12 ± 0.00
C18:0 Stearic acid	7.82 ± 0.08
C18:1 Oleic acid	30.63 ± 0.27
C18:2 Linoleic acid	25.5 ± 0.06
C18:3 Linolenic acid	3.03 ± 0.03
C20:0 Arachidic acid	0.41 ± 0.04
C 20:1 Gadoleic acid	0.38 ± 0.02

[a] Data are reported as mean ± standard deviation.

Table 5. Mineral content of secondary food product.

Element	
Ca [a]	1.17 ± 0.08
P [a]	0.23 ± 0.07
K [a]	0.66 ± 0.10
Na [a]	0.61 ± 0.05
Mg [a]	0.15 ± 0.05
Fe [b]	2.21 ± 0.02
Zn [b]	155 ± 47.3
Mn [b]	47.2 ±2.33
Cu [b]	22.4 ± 2.55

[a] Values in % calculated on dry matter, [b] Values in mg/kg (ppm) calculated on a moisture basis of 12%.

3.3. New Perspectives: Applicability in the EU

Figure 2 outlines the main results with reference to the applicability analysis. With respect to the legal framework on food waste and feed production currently in force, the case study analyzed has proven not to be fully suitable for implementation in the EU due to two main drawbacks: The nature of the raw material used as input for the food waste transformation process and, secondly, the destination of the final product.

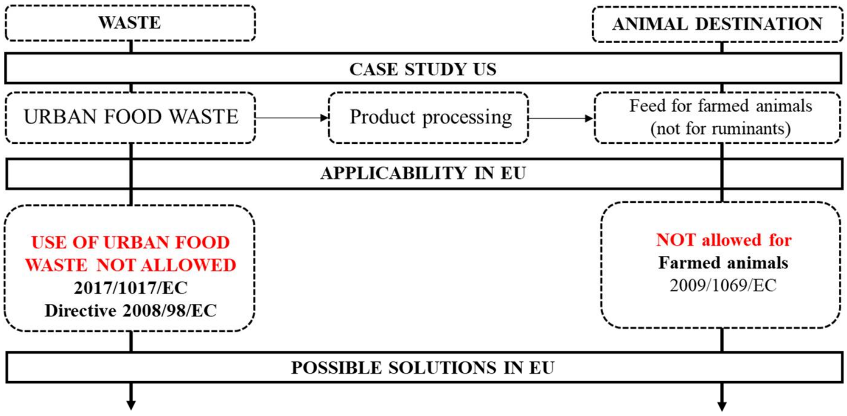
More specifically, with regard to the type of waste used, the US case study processes urban food waste, which is not allowed in the EU in accordance with Directive 2008/98/EC which considers food and kitchen waste from households, restaurants, caterers and retail premises as bio-waste for composting and digestion. Despite the fact that the final product analyzed showed its compliance with safety requirements and a good nutritional profile, the European approach, which does not permit urban waste to be used as raw material for the food chain, can be considered as the best solution for public health protection.

Nevertheless, a large proportion of food waste that could be legally recycled under the current legislation already exists, as provisioned by the Commission Regulation No. 1017/2017 in the catalogue of feed materials. More specifically, the Regulation includes former foodstuffs (Figure 2, source 1), defined as food products manufactured for human consumption in full compliance with the EU food law but which are no longer intended for human consumption for practical or logistical reasons. The second type of source is fruit and vegetable surplus, which is composed of surplus derived from the industrial processing of raw fruit and vegetables, such as fruit pulp.

The third type of food surplus identified is catering reflux, defined by Regulation 2017/1017/CE as all waste food containing material of animal origin originating in restaurants, catering facilities and kitchens, including central kitchens and household kitchens. The food material comprised in this category can be considered as one of the most interesting sources for animal feed production and derives from three main origins: Sludge due to kitchen procedures, the food surplus generated by unconsumed food portions (which can also be redistributed for human consumption) and plate leftovers, under specific safety conditions determined by HACCP procedures.

Source 4, namely the fish and meat surplus, is composed of animal products or by-products with or without treatment, such as fresh, frozen and dried food products.

The second critical point relates to the final destination of the product, namely the type of animals that can be fed with the product originating from the food waste treatment. EU legislation Reg. No. 1069/2009 stipulates the health rules regarding animal by-products and derived products not intended for human consumption. However, it does not permit the feeding of farmed animals with processed animal proteins. This measure derives from past crises related to outbreaks of foot-and-mouth disease, the spread of transmissible spongiform encephalopathies such as bovine spongiform encephalopathy (BSE), and the occurrence of dioxins in feedstuff.



1. Former food	2017/1017/EC	Farmed animals, aquarium fish and pets
2. Fruit and vegetable surplus	2017/1017/EC	Farmed animals, aquarium fish and pets
3. Fish and meat surplus	2017/1017/EC 2009/1069/EC	Aquarium fish and pets
4. Catering reflux	2017/1017/EC, PART C (list of feed materials), number 9.9.1 2009/1069/EC	Aquarium fish and pets

Figure 2. Applicability analysis of US case study for the EU.

Notably, sources 1 and 2 (former food and fruit and vegetable surplus) can be used for farmed animals, since the absence of animal proteins makes them suitable for transformation into livestock feed within the EU safety requirements.

Furthermore, all the sources listed in Figure 2 can be used for the manufacturing of pet food including catering reflux, under specific conditions. This is particularly noticeable since the European Pet Food Industry Federation in 2014 reported an annual growth rate of 1.8%, with 9 million tons in volume of annual sales of pet food products, and a turnover of 15 billion euros [33]. Given the size of the industry, the adoption of sustainable practices could have a significant impact globally. Moreover, protein is the most expensive macronutrient in ecological and economic terms, and therefore the one requiring the most attention with respect to sustainability [34]. In fact, the animal protein content significantly determines the environmental impact of dog and cat food formulas, and there is an increasing demand for culturally-acceptable products for pet owners, while still being nutritious and palatable to the pets [35,36]. Eco-conscious pets-owners wish to balance their pets' dietary needs with protecting the planet. Thus, the development of controlled measures for collecting, transporting and storing raw materials is the principal condition for the safe use of the raw materials identified as livestock feed or pet food.

4. Conclusions

In terms of the global impact, the results of the present study highlight that *feed-from-food* strategies can be implemented within the European legal framework and represent a highly sustainable way of reducing the socio-economic costs related to food waste, resulting in a more efficient food chain.

The fact that the process uses food scraps as raw material implies that the costs related to food waste disposal and treatment are expected to be significantly lower. The secondary food product could also partially replace the traditional raw materials needed for feed and consequently provide a potential land/water saving for crop cultivation. In addition, the reduced competition among food/feed/energy crop use could reduce the environmental impact of feed production.

The system analyzed would seem to have a positive socio-economic impact and to successfully contribute to the improvement in the global sustainability of the agri-food system, in accordance with the objectives of the circular economy.

The results of the study also highlight the wide margin of improvements for food waste prevention within the current EU framework, without necessarily changing regulations on food waste management. However, the basis for the implementation of the proposed strategies consists in the development of controlled systems that would guarantee that the food surplus is collected and managed in compliance with the most stringent safety requirements.

Supplementary Materials: The following are available online at http://www.mdpi.com/2071-1050/10/6/2035/s1, Section SA: Collection, transport and delivery—primary food product waste; Section SB: Production pre-processing; Section SC: Processed product drying—secondary food product.

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