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Combating Food Waste with Sustainable Poultry Feed and Fertilizer Production

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Abstract

Industrial and commercial operations produce the majority of Food Waste (FW), and the majority of FW produced by households as part of the general waste collection and is moreover burned or dumped. Collecting FW constitutes a distinct kind of trash, and using it to generate compost or recapture energies via anaerobic digestion (AD) is gaining popularity. This study determined to employ FW to make Poultry Feed and Liquid fertilizers (PFLF). The service café, club, bakery, supermarket, and restaurant all contributed to the gathering of the FW samples for this study. The PFLF method generated poultry feed pellets (PFP) with a protein level of 20%. This is within the range of 17 to 25%, typical of most commercially available PFP, and falls within the range suggested by the National Research Council (NRC), which is 18 to 27%. The liquid extract from PFLF may thus be used in hydroponic systems instead of the commercial Liquid Fertilizer (LF). The PFLF process may provide environment credits for 17 parameters out of the 20 categories of effects taken into account in the study, according to the results of the life cycle analysis (LCA) application study of the process's environmental impact. The measured ecological credits remained much higher compared to AD, incineration, and landfills as alternatives to disposal.

Keywords: Liquid Fertilizer (LF), Hydroponic, Poultry Feed Liquid Fertilizer (PFLF), Food Waste (FW), Poultry Feed (PF).

Introduction

The Food loss and waste pose a danger to future food systems' sustainability. According to estimates from the United Nations Food and Agriculture Organization (FAO), around one-third of the food produced worldwide meant for human consumption is lost or squandered. Although the phrases food losses (FL) and FW are often used together, several studies have attempted to distinguish between the two terms depending on the phases of a food supply chain. Customers at the sales and consumption levels toss food away, known as FW. Food that is left unfinished throughout the manufacturing, post-harvest, and processing stages of the food supply chain is referred to as FL (1). FW from homes, commercial service facilities like restaurants, institutional cafeterias, hotels, and industrial sources like staff lunchrooms have increased due to higher living standards and dietary changes. The garbage often included scraped food, leftover meals and cereals, fruit peelings, vegetable leaves, and dairy products. If food waste is dumped illegally at dumping sites, it might cause public health issues relating to its biological components and the water it contains (2). Recent concerns about Food Loss and Waste (FLW). The circular economy, sustainable development, and resource conservation have raised public awareness of these issues. Such wastes, including lignocelluloses, proteins, oils, and grease, would represent resource depletion and waste if not valued for manufacturing bioenergy and goods with value added (3). The critical worldwide problem of FW requires an immediate response. Huge amounts of usable food are unnecessarily wasted daily, depleting resources and aggravating issues with hunger and the environment. Food is wasted at many manufacturing, storage, transportation, and consumption phases from farm to fork. In addition to harming the economy, this wastefulness also increases greenhouse gas emissions and depletes water and land resources (4). Competence between food and feed and the scarcity of land, fertilizer, energy, and water all impact the capacity to produce feed. High feed costs affect the poultry industry because farmers make less money. Price increases for chicken and eggs might cause social and political upheaval. These problems provide difficulties for the environment, people, and cattle production taken as a whole. The larvae are abundant in micronutrients and critical amino acids like lysine, threonine, and methionine but severely deficient in poultry diets based on grains and legumes (5). One of the fastest-growing segments of the global and Indian livestock industries is poultry. In India, broiler meat output is growing at seven percent to eight percent annually, while eggs are increasing by five percent to six percent. Based on the 20th livestock census, the total number of poultry in the nation was 851.81 million in 2019, an increase of 16.8% from the previous count in 2012. This shows a significant rise in backyard poultry birds, which increased by 46 percent between 2012 and 2019 (6). The poultry industry is expanding quickly globally and helps achieve important national development objectives and raise people's living standards by reducing poverty and opening up job opportunities. The issue with chicken farming is the manure that must be dealt with since improper treatment or disposal may endanger both people and the environment. The poultry industry produces Solid waste and wastewater in huge quantities. Feathers, shells, feces, feed, bedding material, hatching waste, wastewater, and mortality comprise solid waste (7). Over the last several decades, poultry output has increased significantly. With 122 Mt produced worldwide in 2017, poultry meat, which comprises 89% of all meat production globally, was the most abundant. Among the major livestock production chains, poultry products are acknowledged as being the most ecologically friendly, along with milk, particularly in terms of carbon footprint and resource depletion (8). An increasing need for fertilizers is brought on by the continuous worldwide population growth and the need to boost agricultural output to meet the demand for food. However, there are growing worries over the long-term viability of non-renewable mineral sources for fertilizer production, particularly phosphate (P). However, it is still debatable as to whether or not these worries are well-founded (9). The poultry business has developed into one of the most significant segments of the world economy due to the enormous demand for poultry meat, eggs, and other goods from the world's continually growing population. There are several environmental problems due to this rapid expansion, including soil and water contamination. The globe uses a lot of

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different antibiotics every year to treat, prevent, and mitigate infections in the livestock and poultry industries (10). This study focused on utilizing food waste in producing Poultry Feed Liquid fertilizers (PFLF). The following parts of the article are organized as follows: An overview of related works is given in Section 2, a more thorough explanation of the materials and method is given in Section 3, and experimental data sets and simulation results are presented and discussed in Section 4. Section 5 discussion and section 6 concludes the study and offers suggestions for more research.

Globally, nationally, and specifically within California (USA), the study of food waste was considered. Every day, a lot of FW is created. The findings of earlier studies imply that FW may be effectively included in the diets of monogastric animals. FW, which occurs across the food supply chain, may partially be used in certain broiler diets to replace maize and soy (11). As a scientific issue and commercial potential, insect bioconversion is gaining popularity. Fowles and Nansen talk about using insects as food waste converters while maximizing their potential advantages (12).The study (13) analyzed several studies with a particular emphasis on activities linked to chicken abattoirs to highlight good management practices from an environmental standpoint. The analysis found that high-quality wastes need innovative and effective processing methods to identify potential feed additives for fish or other animal meals and alternative waste treatment methods that could recover energy and high-quality bio-nutrient sources for crop production. The paper (14) assessed the inefficiencies in turning FW into animal feed and recognized their origins. It was predicted that enterprises that convert food scraps from stores and services into animal feed would severely lose production efficiency due to the COVID-19 epidemic. In addition to enforcing rigorous restrictions, Vietnam has to be more proactive in its responses and attempts to address FW concerns (15).The study (16) discusses the many FW production sources, whether to use them and the method to value them by using microbes. Using microorganisms, whether aerobically or anaerobically, to produce biofuels, biosurfactants, electrical energy, bioplastics, and biofertilizers, among other products, maybe a sustainable and advantageous solution for managing FW. The paper (17) provided the ideal environment for housefly larvae to breed on food waste. These results demonstrate that the products produced by the conversion of FW by housefly larvae may be used to make fish meals. The most common pretreatment method involves both pretreatment and a three-phase separation, while anaerobic digestion is used as the main pretreatment approach in 76.1% of the current FW pilot projects. Regarding FW formation and the ability to cure FW, important geographical factors have been recognized. There was also a discussion of potential variables affecting Food Waste Management (FWM) in China (18).The study (19) combined the recent data on FW-based industrial mass breeding of palatable insects for food and feed. It was also evaluated if the fermentation process could be used to mass produce edible insects and what effect this method of rearing would have on the development of a food sector that is both sustainable and kind to the environment. A significant amount of nutrients may be recovered from FW and fed to edible insects that can adapt their diets. The paper (20) analyzed FW in feeds for ruminants, fish, swine, poultry, and

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rabbits. It also evaluates relevant safety and logistical issues. According to the findings, different food wastes and losses may be processed using contemporary technology to create safe feeds that may be added to animal diets. A model of resource recovery driven by zero solid discharge has been proposed in this case. Several novel biological mechanisms for FWM while providing a comprehensive assessment of their technical viability and environmental sustainability (21). The quantity of phosphorus lost during food production will be determined using a phosphorus loss factor produced by material flow analysis. The findings provide important details on the quantity and make-up of FW and its effects on the environment and phosphorus resources at the provincial level (22).The study (23) examined the claim that chicken litter does not currently satisfy the requirements for use as organic fertilizer. Technical reports, conference transcripts, peer-reviewed journal publications, and online texts were all analyzed in the study. There are significant differences across nations and organizations charged with setting standards for the safe disposal of organic wastes, even when rules exist for related products like compost. The paper (24) examined the most recent issues and developments in the management of post-consumer FW and evaluates its potential for producing biochar and biofuel. The main aspects of post-consumer FW are identified, along with disposal options and recycling via chemical, biological, and thermo-chemical conversion. The study (25) examined the presence of mycotoxins, a few plant and bacterial metabolites, and 24 feed additives in Machakos town, Kenya, between February and August 2019. It used a recognized multi-toxin liquid chromatography-tandem mass spectrometry method to analyze the materials. The samples included 153 mycotoxins, plant toxins, and bacterial toxins altogether.

Materials and Methods

Sustainable PFLF is an all-encompassing and environmentally-friendly approach to the problem of food waste. Promoting soil health and increasing agricultural productivity, organic fertilizers from food waste are a sustainable and environmentally friendly alternative to synthetic chemical fertilizers.

Production Process and Raw Materials

Samples of FW totaling around 11 kg were collected from various service clubs (SC), restaurants, bakeries, cafes, and Fruit and Vegetable (FV) market areas for two hours on a designated day throughout the summer, winter, and spring. Within two hours of collection, Western Sydney University (WSU), giving out capability, processed the FW samples. The building is on the WSU campus in Hawkesbury, near the FW collecting locations. This made it possible to transmit the samples gathered for processing quickly. The (Figure 1) illustrates the six processing steps that went into making the PFP.

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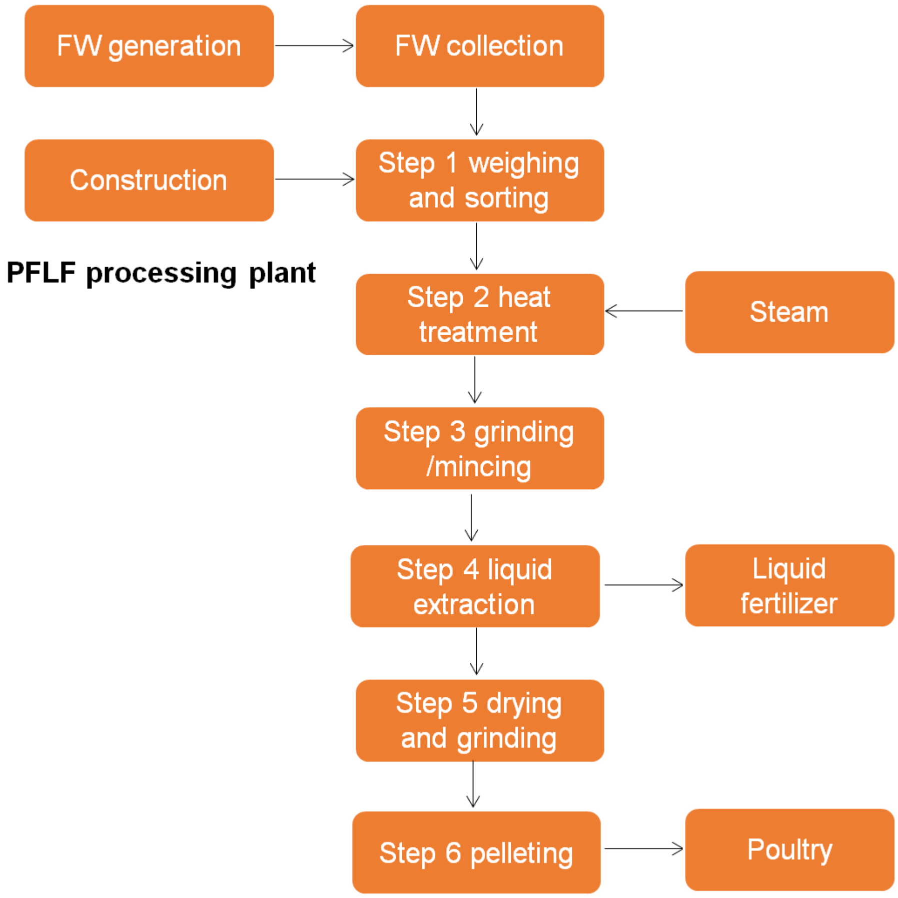

Figure (1): The FW and PFLF manufacturing and life cycle phases

The LF was destroyed in the first three methods, all of which included grinding or mincing. While being weighed and organized, samples of food were Step 1 prepared by removing any debris such as bones, plastic wrap, or paper towels. The Step 2of the process was steam tunnel heating. In this method, materials were heat treated in steel trays. A conveyor belt carrying the sample trays was lowered into a steam tunnel. For 10 minutes, steam was used to get the samples up to 93 degrees Celsius. Step 3 of the heat treatment included grinding the materials into powder in an industrial grinder. In step four, the ground samples were passed using a 152-micron nylon filter to retrieve the LF. The content of macronutrients in the collected liquid fertilizer was examined. Step 5 included weighing and dehydrating the ground samples at 70°C for 4 hours in a big professional dehydrator cabinet after being put on disposable aluminum trays. Samples were reweighed after dehydration, and moisture loss was computed.

Step 3 of the heat treatment included grinding the materials into powder in an industrial grinder. Step 4 involves filtering the grounded samples with a 155-millimeter nylon filter to get the LF. The content of macronutrients in the collected liquid fertilizer was examined. Step 6 included weighing and dehydrating the ground samples at 75°C for 4 hours in a large

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professional dehydrator cabinet after being put on disposable aluminum trays. Samples were reweighed after dehydration, and moisture loss was computed. The dough was made by combining water and dried PF powder in a 56:44 ratio. A rotary cutter and a number 8 die were used to extrude the dough via the Bottene pasta extruder. This action resulted in 3 x 6 mm pellets. At 70°C for 24 hours, these pellets were dehydrated. The pellets' moisture, fat, protein, Calcium (Ca), Magnesium (Mg), Sodium (Na), potassium (K), and Phosphorus (P) contents were measured.

Analysis of the Parameters and the Techniques

The LF was tested for pH, electrical conductivity (EC), total phosphorus (TP), filterable reactive phosphorus (FRP), total nitrogen (TN), and NO3-N. The cations tested included sodium, calcium, and magnesium. The methods described in APHA (1998) were used to conduct the analysis for total solids (TS). Using a multimeter 40D, pH and EC were measured. Standard techniques were used to determine the amount of moisture. Soxhlet equipment was used to determine the total fat content. The LCA of one of the FW was examined for several FWM techniques, including PFLF, AD, incineration, and landfilling. This comparison's range extends from the moment at which trash is created in the home to the time at which materials produced via PFLF, AD, incineration, and landfill reach the end of their useful lives. Among other similar assumptions, it was thought that FW was isolated from its surroundings throughout its formation. Energy and emission costs were not considered during the planning and building of wastewater treatment plants. It was estimated that municipal garbage trucks weighing 21 tonnes were used to collect FW.

Results

Appropriate PF production guarantees that food scraps are used to their full potential as a valuable resource, resulting in a low-cost and high-nutrient feed for poultry. This, in turn, encourages efficient poultry production and sustainable cattle rearing.

The beginnings and features of FW

A total of 10 kilos of FW samples were gathered for PF processing, as reported by each of the nine different sources. Service clubs (SC), eateries, nursing homes, bakeries, and FV markets comprise the other nine establishments listed in (Table 1). The moisture, lipid, and protein contents of each of the nine collected samples were examined. Table 1 displays the resulting quantities of dry material from different waste sources.

Table (1): Sample dry solids yield from trash, tabulated

Source o sample	**Dry solids (%)**
Café 1	32
Restaurant	16
FV	8
Café 2	27

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Retirement home	26
SC	26
Bakery	66

The productivity of dry solids that could be recovered ranged from 5% for FV garbage to sixty-five percent for bakery waste. The waste from bakeries was the least wet. After heat treatment, the (Table 2) shows each of the mineral content of the Raw Waste Samples (RWS). The (Figure 2) lists the fat content of RWS.

Table (2): Numerical outcomes of Fat and protein of RWS

Mineral contents of RWS		
	Fat	**Protein**
Cafe	13.5	13.1
Restaurant	25	38.5
Fruit and vegetable	54.8	12.4
Retirement home	23	28
Bakery	6.5	15
Service club	17	41

The lipid and protein levels of the waste samples varied from 38.5 % (protein), respectively. The outcome showed that utilizing waste samples makes it possible to make PF with a fat content ranging from 54.8%, depending on the needs. One of the most crucial aspects of PF is the protein content.

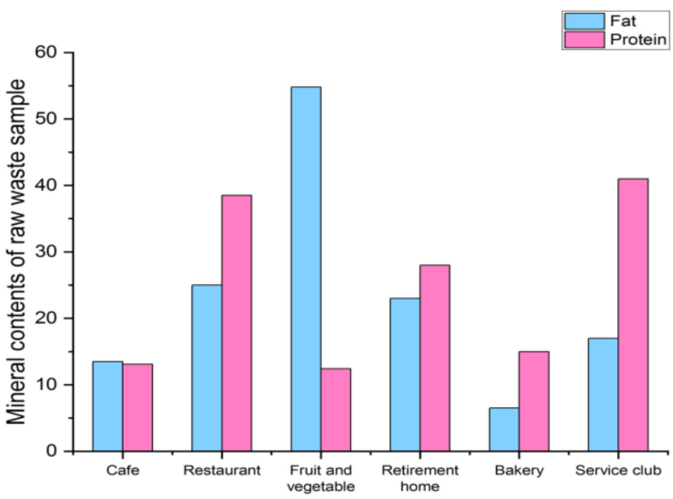

Figure (2): Fat and protein of RWS

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Additionally, the cost of components for protein-rich feed is rising due to a shortage. The (Figure 3 and Table 3) list the mineral contents (K, P, and N) of raw waste samples composition of dried waste samples and extruded pellets. The results unequivocally show that FW can be used to make protein-rich, affordable food ingredients.

Table (3): Numerical outcomes of Mineral contents (K, P, and N) of RWS

Mineral contents of RWS			
	Potassium (K)	Phosphorus (P)	Nitrogen (N)
Cafe	4082	2091	19521
Restaurant	8883	3041	57923
Fruit and vegetable	13401	1743	18884
Retirement home	6432	2722	44648
Bakery	5108	1115	16005
Service club	2708	2691	64641

The sample has a mineral content of around 40%, comparable to the protein composition of certain popular high-value meals. This could be caused by the FW's high meat or pulse content. This further emphasizes how FW features vary depending on the source of collecting.

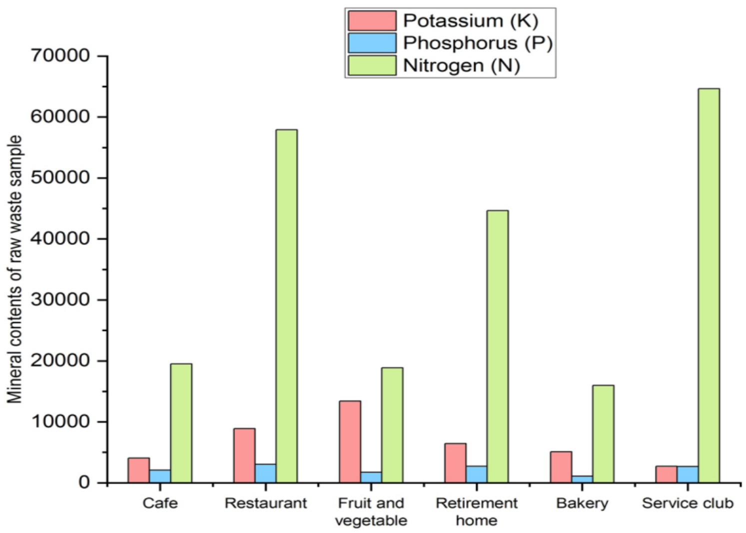

Figure (3): Mineral contents (K, P, and N) of RWS

Variation might take place on a daily, weekly, monthly, or even yearly scale. It's possible that this is one of the most significant challenges to overcome when trying to produce consistently superior PF from FW. The nutritional value and other mineral content of FW were high, and as can be shown in Figure 2, the protein level ranged from 10 to 40%. FW has a protein

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content that is similar to that of soybeans, although having a level of protein that is noticeably higher than that of maize and only slightly lower than that of Meat and Bone Meal (MBM).

Table (4): Numerical outcomes of Mineral contents (Na, Mg, and Ca) of RWS

Mineral contents of RWS			
	Calcium (Ca)	**Magnesium (Mg)**	**Sodium (Na)**
Cafe	515	458	4595
Restaurant	635	445	10908
Fruit and vegetable	1018	765	1145
Retirement home	1630	548	11408
Bakery	395	328	4679
Service club	282	575	3248

In comparison to samples from cafés, SC, and restaurants, those from bakeries and FV FW had lower quantities of protein and fat. This is explained by the fact that fruits and vegetables predominate in bakery and FV trash (Figure 4 and Table 4).

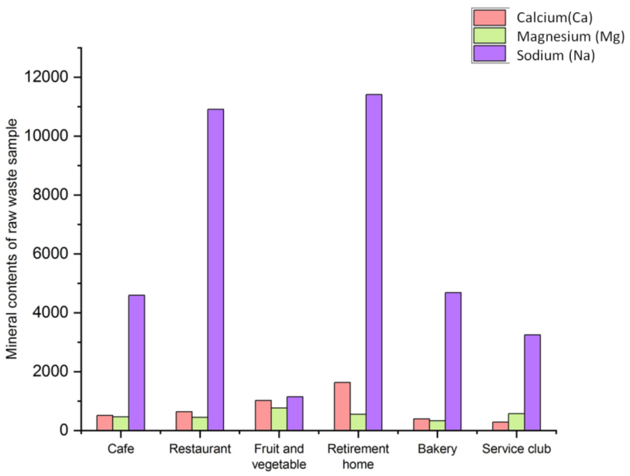

Figure (4): Mineral contents (Na, Mg, and Ca) of RWS

The garbage from restaurants, cafes, and SC, on the other hand, may include food items like poultry, pig, beef, and fish abundant in protein and fat.

Merging of FW and Feed Pellet Production

Poultry needs a diet of nutrients to sustain body growth or egg production. Protein, vital amino and vitamin acids, fatty acids, minerals, and water should all be part of a nutrient-dense meal.

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Table (5): Numerical outcomes of Formulation of PF from chosen ground samples based on a dry weight

The dry weight of the sample	
Cafe	190
Restaurant	125
Fruit and vegetable	37
Retirement home	220
Bakery	526
Service club	115

A proper ratio of FW streams was used to generate 50 percent of the dry weight of the sample (Table 5 and Figure 5).

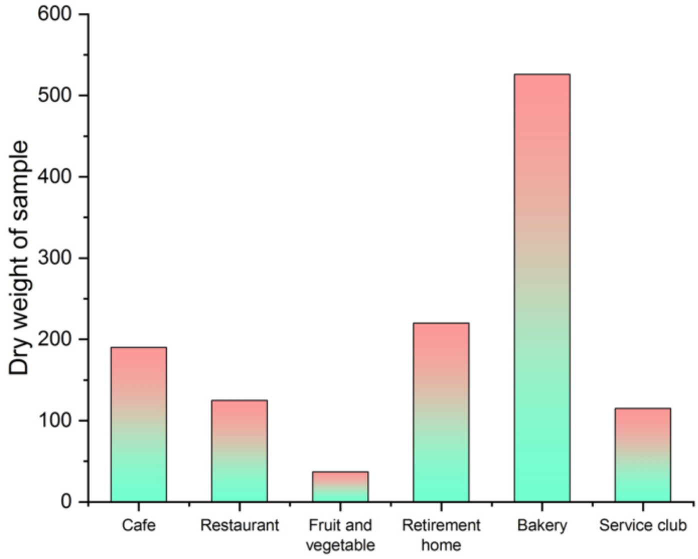

Figure (5): Formulation of PF from chosen ground samples based on a dry weight

The data shows that the bakery's food waste contributed the most to the final feed composition, at 38.3%.

Percentage	
Cafe	13.6
Restaurant	10.11
Fruit and vegetable	2.8
Retirement home	17
Bakery	39.2
Service club	8.5

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Due to the properties of FW, it is feasible to recycle and generate premium feed for pigs, poultry, and pets. Heat treatment will be used throughout the processing of the FW to guarantee its microbiologically soundness and product quality. By doing this, it will be easier to utilize the soy and grains, like maize or wheat, used to make PF (Table 6 and Figure 6).

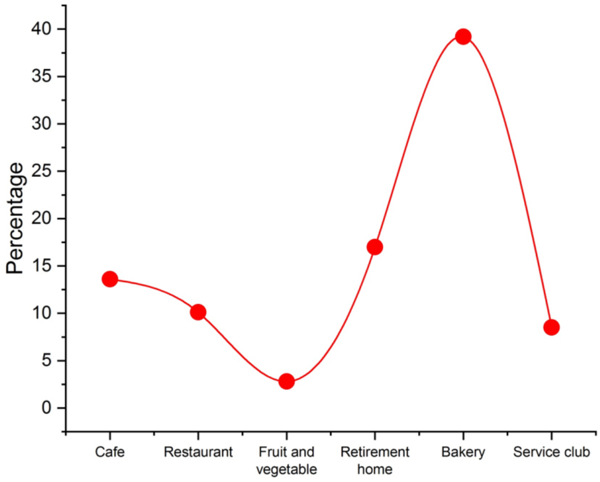

Figure (6): Formulation of PF from chosen ground samples based on a percentage

Due to its low-fat content, convenience of collection, and favorable storage conditions, bakery trash is more common in garbage streams than other forms of food waste. Due to actual variances across waste types, these ratios will need to be modified. Important nutrients can only be detected by quick analytical procedures. After the feed is ground into a powder, it is mixed with water, extruded, and dried to form pellets. The pellets' 18.7% protein content was within the NRC's recommended range and the acceptable range of 16 to 22% for the bulk of commercial PFP. Additionally, as indicated in Table 4, the mineral composition of the new PF is within the range recommended for both laying and meat birds.

Liquid fertilizer

There is no published information addressing the removal of LF from the procedures involved in the manufacturing of animal feed. Unfortunately, it has been observed in several tests that digestate supernatant, collected from the anaerobic following the time the FW was fed there, was used.

The extracted liquid's total solids (TS) level, which ranged from 4 to 18%, was very high. Compared to the FV sample, the TS for the SC sample was substantially greater. This is because cooking food may result in the production of finer particles than growing veggies in their raw state. As greater fiber is present in raw veggies, this is to be anticipated. In order to reduce the amount total particles in the liquid extract, the samples were ground up for 15

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minutes at a speed of 4,000 revolutions per minute. After being subjected to centrifugation, a significant amount of fat was recovered on top of the liquid extract that was taken from the SC FW sample.

Table (7): Features of recovered LF from various sources of garbage

Nutrients	Unit	Pellets (this study)	Sample no	Sample source	Dry solids (%)
Fat	Percent (Per)	16.1	11		14
Protein	Per	19.8	18.7	16	61
Ca	Mg and kg	981	10.000	9668	30,000
Mg	Mg and kg	501		61	
Na	Mg and kg	6,531	2,801	1,567	
K	Mg and kg	5.631		3,001	
P	Mg and kg	3.520	5,332		18,000
N	Mg and kg	29,921		33,534	
Lysine	Per	0.4	0.8	0.7	
Methionine	Per	0.2	0.4	0.4	
Arginine	Per	1.9		0.8	
Typtophan	Per	0.2	0.2	0.2	

The (Table 7) displays the characteristics of LF recovered from four distinct FW sources. Out of these, three FV streams come from fruit and vegetable shops throughout the winter, spring, and summer. The availability of some fruits and vegetables varies throughout the year, which may account for these differences.

Recycling in the Food Industry, Consumer Culture, and the Circular Economy

Despite generating more waste products, the FW may fully transform into two beneficial effects: LF and PF. This may result in a circular economy for the creation, consumption, and recycling of garbage. FW is highly biodegradable, and its contribution to greenhouse gas emissions is nearly on par with global transportation emissions. Consequently, implementing this circular economy strategy will help the economy, society, and environment locally, nationally, and internationally.

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LCA of Alternate FWM

The major purpose of this section is to calculate the environmental effect of utilizing FW to produce PFLF and to compare it to those resulting from other processes, including AD incineration and landfilling. The present method lessens the load on cash crops like maize and soy for making poultry feed while preventing FW from going to the garbage. Additionally, it generates LF, which may result in the production of fruits and vegetables.

The environmental effects of alternative FWM, including the manufacturing and use of PFLF and LCA, are essential. From the collection and processing of FW through the creation and use of LF, LCA analyzes the whole life cycle of this FWM method. It examines several variables, including energy use, greenhouse gas emissions, water use, and possible soil and water quality effects. LCA gives useful information on the sustainability of utilizing PFLF to manage FW by measuring these factors. This study aids stakeholders in comprehending the environmental trade-offs and locating opportunities for advancement to reduce the ecological impact of this specific FWM strategy.

Discussion

Global FW refers to wasting food at any stage of the food supply chain. This includes production, processing, distribution, and consumption (26). In addition to contributing to environmental damage, it represents a huge loss of important resources, including water, energy, and land (27). FW wastes the labor put into its production and makes problems like poverty, food insecurity, and economic inefficiencies worse (28). PF is a crucial part of the poultry business since it gives poultry birds the nutrition they need for development, health, and production. It is designed to satisfy the unique nutritional needs of different poultry species, such as chickens, turkeys, and ducks. A well-balanced mix of grains, protein sources, lipids, vitamins, minerals, and additives make up most PF (29). These components were chosen with great care to provide the best nourishment and promote the growth of strong bones, feathers, and general body condition. The creation of nutrient-rich formulations customized especially for the requirements of poultry husbandry is the main goal of poultry fertilizer manufacture. As a byproduct of raising chickens, poultry dung is often used as a useful resource for fertilizer production (30). The potential advantages of using FW as a valuable resource within the poultry sector are highlighted by using FW with sustainable chicken feed and fertilizer production. FW reduction and sustainable agriculture may be addressed concurrently by diverting FW toward the production of fertilizer and feed for poultry. This strategy not only lessens the quantity of FW that ends up in landfills, but it also offers a sustainable supply of nutrients for PFLF.

Conclusion

The FW is a resource that has important nutrients. Additionally, the disposal of FW via landfills and incineration may result in the release of hazardous greenhouse gas emissions that have an adverse effect on the environment. This study demonstrates that generating PFLF using FW is feasible. The findings indicate the possible economic advantages of recycling FW and resulting in a circular economy for the creation, consumption, and recycling of trash. The PF generated was of comparable quality to that on the market, and the LF produced had nutrient contents comparable to those seen in commercial feed solutions used in hydroponic systems. Utilizing food waste as a source of feed or fertilizer has certain drawbacks, including the possibility of contamination and food safety problems. Maintaining a consistent supply for the manufacturing of PFLF may be challenging because of the variable availability and consistency of FW as a resource. A more resource-efficient and circular food system may be achieved by incorporating FW into manufacturing fertilizer and PF. This will increase the sustainability, safety, and economic viability of this practice.

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