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Nutrient Evaluation of Dining Center Food Waste and Comparison to Monogastric and Ruminant Feedstuffs

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Abstract

The objective of this study was to analyze the nutrient composition and variability of university dining hall food waste and compare it with common feedstuffs used in ruminant and monogastric diets. Food waste was categorized into two initial streams: mainstream (MS) from the serving line and vegetable preparation (VP) from the kitchen. Waste was collected from the Kramer Dining Center, Kansas State University, resulting in 30 daily samples. Waste was weighed and ground to homogenous particle size. Daily samples of MS and VP were analyzed for nutrient composition, where results were combined to calculate the nutrient profile of a hypothetical mixed food waste stream (MX) composited by total weight. Data were analyzed using R statistical software (v 4.2.2). Moisture and neutral detergent fiber (NDF) were greater in VP ($P < 0.05$), while ether extract (EE) was less compared to MS and MX. Crude protein (CP) was greater ($P < 0.05$) in MS and MX streams compared to VP. The total digestible nutrients (TDN) and energy were greater in MS food waste than in MX, which was also greater than VP ($P < 0.05$). Variability of nutrient content, measured by standard deviation, was similar ($P > 0.05$) among streams for NDF, nitrogen-corrected neutral detergent fiber, acid detergent insoluble crude protein, CP, ash, lignin, and digestible and metabolizable energy. Dry matter and EE variation were greater ($P < 0.05$) in MS, whereas VP was less ($P < 0.05$) compared to MX. Standard deviation increased ($P < 0.05$) in MS and MX for neutral detergent insoluble crude protein, TDN, and gross energy when compared to VP. Despite having 70% - 80% moisture, dining hall food waste does have nutritive value and the potential to be included in ruminant and monogastric diets. Further research needs to be done to understand the value of including it in animal diets.

Keywords

Food Waste, Feedstuffs, Monogastric, Ruminant, Nutrient Variability

1. Introduction

Food waste is commonly thought of to be edible food that was intended for human consumption and, for various reasons, is not utilized and discarded [1]. Approximately 30% to 40% of all food in the United States is not used and eventually ends up in a landfill, estimated to be about 133 billion pounds [2]. This contributes to the unnecessary use of fresh water and fuel as well as emitting greenhouse gases like methane and carbon dioxide from decomposing food without any human benefit [3]. The Environmental Protection Agency created a Food Recovery Hierarchy to help mitigate food waste and illustrate how to redirect food waste for greater utilization [4]. Part of this hierarchy is the option to use food scraps and waste to feed animals. Currently, it is being reported that only about 12% of retail waste and 1% of restaurant waste are being recovered for animal feed, while 45% and 97% of food waste from retailers and restaurants, respectively, are being disposed of in landfills [5] [6]. In one study where different sources along the food supply chain were analyzed for nutritional value, waste had greater nutritional value than corn or soybean meal, but was also more variable [7]. The vast percentage of waste being generated daily that goes directly to the landfill and the high variability led us to focus on food waste from a cafeteria dining hall.

Cattle are already great recyclers because of the large range of feedstuffs that they can process and use with the help of rumen microbial fermentation. Because of this, based on location and availability, they can utilize nutrients from vegetable and fruit scraps and even rejected candy [8] [9] [10]. When looking at the potential use in swine diets, a study was conducted at the University of Minnesota by Fung *et al.* [11] to test several different sources of food waste in a digestible and metabolizable energy (DE and ME) study. They found that one source, what they characterized as "supermarket waste", had greater energy concentration than corn when fed to swine (5071 and 3928 kcal/kg DE and 4922 and 3875 kcal/kg ME, waste and corn, respectively). Another source they used, "fruit and vegetable waste", had lower energy concentration than corn (2570 and 3928 kcal/kg DE and 2460 and 3875 kcal/kg ME, waste and corn, respectively), suggesting that some waste sources could be beneficial energy sources for use in swine diets [11]. However, there has been little research on exactly what nutrients are available to the animal and how, if at all, food waste compares to feedstuffs that are already commonly used. In addition, there are challenges with transportation, processing, and nutrient variability. For food waste to be included in animal diets, the unpredictability and variation of types of food can be an issue for feed mills from a processing and quality assurance standpoint, but also an issue for nutritionists formulating diets. Therefore, the objective of this study was to determine the nutritional composition and variability of different cafeteria food waste streams and compare nutritional value to common monogastric and ruminant feedstuffs. We hypothesized that there would be a large range of nutritional variability day to day between streams and that separating the MS and VP streams would help reduce the amount of nutritional variability. Additionally, waste such as vegetables and fruits would be more characteristic of high-fiber feedstuffs, while waste such as prepared, cooked meals would relate more to high protein and high starch feedstuffs.

2. Materials and Methods

2.1. Food Waste Collection

Food waste was collected from the Kramer Dining Center, Kansas State University, for 6 consecutive weeks resulting in 30 daily samples. Food waste was initially identified and split into two categories or streams: vegetable preparation (VP) from the kitchen and main (MS) from the serving line. The VP consisted of any food scraps leftover from preparing meals or fruit and vegetables that may have gone bad such as onion peels, pepper stems, whole apples, grapes, or celery stalks. This also consisted of seasonal foods such as melon rinds and pineapple tops. The MS consisted of finished foods that had been out on the buffet line for students and either could not be reheated, repurposed, or donated to a local food pantry. This also consisted of food that could have been burned during the cooking process or the recipe was not followed correctly. Some examples of MS food are combinations of pizza, pasta, rice, scrambled eggs, salad bar fixings, and various desserts. During the collection period, waste was kept separate at the dining center according to streams VP and MS. Each day, food waste was brought back to the lab where it was weighed and ground to a homogenous particle size using either a food processor for VP or a meat grinder (LEM #8, 0.5 HP) for MS. The VP was immediately dried in a 13˚C oven to a constant weight and ground (Bliss Hammermill, Ponca City, OK, 6 mm screen) for a more uniform particle size. Subsamples were taken from MS, dried in a 13˚C oven, and ground (Hamilton Beach Coffee Grinder). Daily VP and MS samples were analyzed for dry matter (DM, AOAC 930.15), acid detergent insoluble crude protein (ADICP, ANKOM Technology Method 14 and LecoTruMac N Macro), neutral detergent insoluble crude protein (NDICP, ANKOM Technology Method 15 and LecoTruMac N Macro), neutral detergent fiber (NDF, ANKOM Technology Method 15), lignin (ANKOM Technology Method 9), and crude fat (EE, AOCS AM 5-04) at Dairy One Forage Testing Laboratory (Ithaca, NY). Ash (AOAC 942.05), crude protein (CP, AOAC 990.03) using a nitrogen analyzer (FP928, LECO Corporation, St. Joseph, MI), and gross energy (GE, Parr 6200 Calorimeter, Parr Instrument Company, Moline, IL) were analyzed at Kansas State University. Nutrient concentrations from VP and MS were used to calculate a weighted value for a hypothetical mixed food waste stream (MX) as follows:

$$\mathrm{MX}\left(\mathrm{Z\ nutrient}\right)=\left(\frac{\mathrm{Weight\ of\ MS}}{\mathrm{Total\ daily\ weight}}\right)*\%\ \mathrm{of\ MS\ Z\ nutrient}$$

$$+\left(\frac{\mathrm{Weight\ of\ VP}}{\mathrm{Total\ daily\ weight}}\right)*\%\ \mathrm{of\ VP\ Z\ nutrient}$$

Nitrogen-corrected neutral detergent fiber (NDFn), total digestible nutrients (TDN), digestible energy (DE), and metabolizable energy (ME) were calculated using the following equations:

$$NDFn = NDF - NDICP$$ [12]

$$TDN = 0.98*\left(100 - NDFn - CP - Ash - EE\right) + \mathrm{e}^{\left(-0.012*ADICP\right)}*CP + 2.25*\left(EE - 1\right)$$

$$+0.75*\left(NDFn - Lignin\right)*\left(1-\left(\frac{Lignin}{NDF}\right)^{0.667}\right)-7$$

[12]

$$DE = 4168 - 9.1*Ash + 1.9*CP + 3.9*EE - 3.6*NDF$$ [13]

$$ME = 4194 - \left(9.2*Ash\right) + \left(1.0*CP\right) + \left(4.1*EE\right) - \left(3.5*NDF\right)$$ [13]

2.2. Comparing Common Ruminant and Monogastric Feedstuffs

In order to compare food waste streams to common ruminant and monogastric feedstuffs, nutrient composition of 29 commonly used feedstuffs were sourced from the Nutrient Requirements of Beef Cattle: Eighth Revised Edition [14] and the Nutrient Requirements of Swine: Eleventh Revised Edition [13]. Nutrient concentrations (CP, ash, EE, lignin, NDF, TDN (cattle), and ME (swine)) for each feedstuff were weighted to each food waste stream's respective nutrient resulting in the absolute relative difference between each nutrient in the feedstuff and food waste stream then summed to give an aggregated relative difference for each food waste stream by feedstuff. The feedstuff with the aggregated absolute relative difference closest to zero was considered the most comparable to the food waste stream. The following equation was used to determine the absolute relative difference of each nutrient then summed together to create an aggregate relative difference for each feedstuff.

$$\mathrm{Relative\ difference}\ \left(z\right)=\frac{\left|\mathrm{Food\ waste}\left(z\right)-\mathrm{Feedstuff}\ \left(z\right)\right|}{\mathrm{Food\ waste}\left(z\right)}$$

2.3. Statistical Analysis

All data were analyzed using R statistical software (version 4.2.2). Descriptive statistics were computed using the *describe* function of the *psych* package. The *levene Test* function of the *car* package was used to test for homogeneity of variance and a pairwise comparison of variances was performed using the *pairwise.var.test* in the *RVAidMemoire* package. The *gls* function of the *nlme* package was used to compare nutrient concentrations of food waste streams. Due to unequal variances, the *varIdent* function was used to generate variance coefficients which were used to describe the within-group heteroscedasticity structure in the *gls* model. The *joint_tests* and *emmeans* function of the *emmeans* package were used to generate an ANOVA table from the *gls* model object and calculate the least square means using a Tukey adjustment and the Kenward-Roger approximation. Means and variances were considered significant at $P \leq 0.05$.

3. Results and Discussion

3.1. Analysis of Food Waste Streams

Food waste was separated into three streams for two initial reasons. First, the Food and Drug Administration passed the Modernization Act of 1997 which prohibits the use of mammalian protein products being fed back to ruminant animals to reduce the risk of bovine spongiform encephalopathy (BSE) infection of additional animals [15]. There are exemptions, however, which include meat products that have been cooked for the use of human consumption [16]. This is because the meat products that were intended for human consumption have been inspected, cooked, and further processed and are considered to pose little risk. So, while food waste is considered exempt from this law, there is no way to guarantee that the food did not come into contact with other meat products or trimmings that were not cooked. Additionally, producers understandably might not want to take that risk for fear of infection and public opinion even if it could be guaranteed that it was all cooked thoroughly. And secondly, separating the streams improves processing efficiency. For example, the VP stream was greater in NDF content than the MS source ($P < 0.05$) and therefore waste could not be ground in a meat grinder as was done with MS. The two streams required different equipment that could handle the two extremes of fiber content.

Table 1 illustrates each of the three waste streams broken down by their average nutrient content, standard deviation, and minimum and maximum value on a dry matter basis. Nutrient values reported for this study were slightly increased from previously conducted research [7]. However, a similar study collecting cafeteria food waste at the State University of New Jersey found very similar nutrient composition to the reported values in **Table 1** showing that location or palate variability could be a potential factor when considering its usefulness in a livestock diet [17]. Moisture content and EE had wide ranges of reported concentrations that could cause concern. All three waste streams contained high moisture that ranged considerably between the minimum and maximum. For example, main stream fluctuated from 44.4% to 93.9% moisture while VP only spanned from 81.0% to 96.0% moisture. Salmonella and other bacteria rapidly multiply in feed that has a water activity level of 40% or greater [18]. This immediately causes concern for rapid spoilage and the need for prompt processing methods. There are multiple processes that could be used to remove excess water in a timely fashion to avoid spoilage such as dry extrusion, spray drying, and dehydration. However, more research would be needed to determine the most

Table 1. Descriptive statistics of nutrients measured in each of the three food waste streams.

	Main Stream				Vegetable Prep Stream				Mixed Stream			
Nutrient	Average	Std Dev.	Min	Max	Average	Std Dev.	Min	Max	Average	Std Dev.	Min	Max
Moisture, %AF	72.23	10.72	44.42	93.92	88.25	3.49	81.01	96.02	76.74	7.09	52.50	90.99
Dry Matter, %AF	27.77	10.72	6.08	55.58	11.75	3.49	3.98	18.99	23.26	7.09	9.01	47.50
Ether Extract, %DM	25.38	10.38	5.90	68.80	3.77	1.36	1.53	6.38	20.18	6.84	4.24	38.11
NDICP[1], %DM	3.72	1.55	1.20	6.60	1.82	0.74	0.60	3.50	3.32	1.23	1.11	5.74
NDF[2], %DM	7.13	5.40	2.40	30.50	21.11	3.93	10.30	27.90	10.27	4.38	4.59	24.34
NDFn[3], %DM	3.41	5.50	0.10	26.70	19.29	3.76	8.70	26.20	6.95	4.83	2.07	21.65
Crude Protein, %DM	21.66	5.72	4.08	32.43	15.19	4.06	5.13	23.25	20.47	3.81	9.51	28.61
Ash, %DM	6.56	2.80	3.06	17.18	9.42	2.83	4.78	17.24	7.50	2.44	5.12	15.33
Lignin, %DM	2.06	1.01	0.70	6.00	2.68	0.98	1.40	5.80	2.14	0.73	1.04	4.93
ADICP[4], %DM	1.07	0.27	0.50	1.70	0.99	0.44	0.40	2.50	1.07	0.21	0.72	1.60
TDN[5], %DM	112.10	13.53	74.58	161.71	74.91	3.10	69.66	82.07	103.09	10.32	74.83	119.90
GE[6], kcal/kg DM	5464.27	388.51	4370.05	6519.11	4268.63	136.34	3951.11	4627.67	5175.63	344.86	4057.58	5618.90
DE[7], kcal/kg DM	4715.80	538.58	2765.95	6027.64	2986.70	258.06	2495.03	3568.27	4291.54	485.87	2877.37	4821.76
ME[8], kcal/kg DM	4598.24	559.60	2708.31	6168.79	2895.25	281.88	2369.79	3559.19	4176.47	489.76	2767.16	4713.40

[1]Neutral detergent insoluble crude protein (NDICP); [2]Neutral detergent fiber (NDF); [3]Nitrogen free neutral detergent fiber (NDFn); [4]Acid detergent insoluble crude protein (ADICP); [5]Total digestible nutrients (TDN); [6]Gross energy (GE); [7]Digestible energy (DE); [8]Metabolizable energy (ME).

effective method while maintaining the nutrient value. Another nutrient worth noting is the amount of EE in the streams, specifically the MS, which ranged 5.9% - 68.8%. While EE is a valuable and expensive component to formulating diets, if it is consistently high it may limit the potential use of food waste. Increasing supplemental fat in feedlot finishing diets to 8% has been shown to decrease ruminal and total tract digestion of organic matter, ADF, and fat which in turn can reduce feed intake due to increased amounts of ruminal solid retention [19]. Thus, finishing diets are commonly formulated at or below 6% total fat. Another factor to consider when potentially feeding high levels of fat is the type of fat. Pigs fed beef tallow have firmer bellies than pigs fed soybean oil, and unsaturated fats, which also, in turn, impacts the marketability of the product [20]. Most dishes are prepared with vegetable oils that have relatively high concentrations of polyunsaturated fat, and thus, is a concern when using food waste in swine diets. There are certain fat capturing processing methods that are used by biodiesel industries which mainly source soybeans for their oil. These methods could potentially be implemented with food waste to capture value for other markets; however, an economic analysis would be needed to determine if a fat expelling step would be beneficial or detrimental to the overall value of the food waste as an energy source. Another limitation of the ability to feed food waste is the high fiber content VP, specifically NDF and NDFn. Lignin, however, was not different ($P > 0.05$) among the three waste streams. High fiber feedstuffs and diets for swine are known to lower energy density and digestibility, decrease protein digestibility, and increase the passage rate resulting in less time for digestion and absorption of nutrients [21] [22] [23] [24].

Table 2 compares the nutrient concentrations of the food waste streams. Mainstream and MX had greater ($P < 0.05$) concentrations of DM, EE, NDICP, and CP than VP. Meanwhile, VP had a greater ($P < 0.05$) concentration of ash than MS and MX, and greater ($P < 0.05$) amounts of NDF and NDFn than MX which also had a greater ($P < 0.05$) amount than MS. In both equations by Noblet and Perez (1993) that were used to determine digestible and metabolizable energy, ash and NDF, which were greater ($P < 0.05$) in VP, were subtracted from the total energy value while CP and EE, which were greater in MS and MX, were added to the total energy value. Not surprisingly, MS had greater ($P < 0.05$) energy (GE, DE, and ME) and TDN concentrations than MX, and MX had greater ($P < 0.05$) energy and TDN than VP. There was no difference between the three streams for ADICP ($P = 0.641$), but MS had less ($P < 0.05$) lignin than VP while MX was intermediate.

Table 3 compares the variability in nutrient content of food waste streams. The MS had greater ($P < 0.05$) standard deviation compared to VP, and MX and MX being increased compared to VP for both DM and EE. The VP had the lowest standard deviation compared to MS and MX for NDICP, TDN, and GE ($P < 0.05$). However, the standard deviation for NDF, NDFn, CP, ash, lignin, ADICP, DE, and ME were not different ($P > 0.05$).

3.2. Comparison of Common Feedstuffs

To further test compatibility of feedstuffs that are commonly used to the food waste streams, 29 feedstuffs were identified, and their aggregated absolute relative difference was calculated and ranked (**Table 4**). It is important to note that each feedstuff evaluation had a different amount of submitted samples thus creating slight variability between sources. This led to the decision to keep feedstuffs and sources separate by species to keep relevancy. The lowest aggregated absolute relative difference was considered the most similar to the respective food waste stream while the highest difference was considered the least similar to the respective food waste stream. The vegetable preparation stream was most similar to citrus pulp for both cattle and swine (aggregated relative difference of 1.40 and 2.04, respectively). More specifically, citrus pulp was most common to VP because of its ash (0.21 [cattle] and 0.10 [swine] relative difference), NDF (0.14 [cattle] and 0.11 [swine] relative difference), lignin (0.09 relative difference for cattle), TDN (0.07 relative difference for cattle), and ME (0.04 relative difference for swine) concentrations. CP (0.55 and 0.52 relative difference for cattle and swine, respectively) and EE (0.35 and 0.27 relative difference for cattle and swine, respectively) were the least compatible nutrients.

The most compatible cattle feedstuff for MS and MX was bakery by-product (aggregated relative differences of 2.54 and 1.84, respectively). Of the nutrients,

Table 2. Effect of food waste collection stream on nutrient content of food waste.

	MS	SEM	VP	SEM	MX	SEM	*P-value*
Dry Matter, %AF	27.77^{a}	2.063	11.75^{b}	0.637	23.26^{a}	1.364	<0.05
Ether Extract, %DM	25.38^{a}	1.997	3.77^{b}	0.249	20.18^{a}	1.316	<0.05
NDICP[1], %DM	3.72^{a}	0.299	1.82^{b}	0.136	3.32^{a}	0.237	<0.05
NDF[2], %DM	7.13^{c}	0.883	21.11^{a}	0.838	10.27^{b}	0.883	<0.05
NDFn[3], %DM	3.41^{c}	0.908	19.29^{a}	0.861	6.95^{b}	0.908	<0.05
Crude Protein, %DM	21.70^{a}	0.883	15.20^{b}	0.837	20.50^{a}	0.883	<0.05
Ash, %DM	6.56^{b}	0.52	9.42^{a}	0.493	7.50^{b}	0.52	<0.05
Lignin, %DM	2.06^{b}	0.177	2.68^{a}	0.168	2.14^{ab}	0.177	<0.05
ADICP[4], %DM	1.067^{a}	0.052	0.987^{a}	0.081	1.07^{a}	0.0397	0.641
TDN[5], %DM	112.10^{a}	2.605	74.90^{c}	0.566	103.10^{b}	1.986	<0.05
GE[6], kcal/kg DM	5464^{a}	74.8	4269^{c}	24.9	5176^{b}	66.4	<0.05
DE[7], kcal/kg DM	4716^{a}	103.60	42987^{c}	47.10	4292^{b}	93.50	<0.05
ME[8], kcal/kg DM	4598^{a}	107.70	2895^{c}	51.50	4176^{b}	94.30	<0.05

[abc]Means without a common superscript within a row differ at *P-value* < 0.05; [1]Neutral detergent insoluble crude protein (NDICP); [2]Neutral detergent fiber (NDF); [3]Nitrogen free neutral detergent fiber (NDFn); [4]Acid detergent insoluble crude protein (ADICP); [5]Total digestible nutrients (TDN); [6]Gross energy (GE); [7]Digestible energy (DE); [8]Metabolizable energy (ME).

Table 3. Effect of stream on the variation (standard deviation) in nutrient concentration of food waste.

	MS[1]	VP[2]	MX[3]	*P-value*
Dry Matter, %AF	10.72^{a}	3.49^{c}	7.09^{b}	<0.05
Ether Extract, %DM	10.38^{a}	1.36^{c}	6.84^{b}	<0.05
NDICP[4], %DM	1.55^{a}	0.74^{b}	1.23^{a}	<0.05
NDF[5], %DM	5.40	3.93	4.38	0.841
NDFn[6], %DM	5.50	3.76	4.83	0.883
Crude Protein, %DM	5.72	4.06	3.81	0.457
Ash, %DM	2.80	2.83	2.44	0.532
Lignin, %DM	1.01	0.98	0.73	0.344
ADICP[7], %DM	0.27	0.44	0.21	0.069
TDN[8], %DM	13.53^{a}	3.10^{b}	10.32^{a}	<0.05
GE[9], kcal/kg DM	388.51^{a}	136.34^{b}	344.86^{a}	<0.05
DE[10], kcal/kg DM	538.58	258.06	485.87	0.335
ME[11], kcal/kg DM	559.60	281.88	489.76	0.381

[abc]Standard deviations without a common superscript within a row differ at *P-value* < 0.05; [1]Main food waste stream; [2]Vegetable preparation food waste stream; [3]Mixed food waste stream; [4]Neutral detergent insoluble crude protein (NDICP); [5]Neutral detergent fiber (NDF); [6]Nitrogen free neutral detergent fiber (NDFn); [7]Acid detergent insoluble crude protein (ADICP); [8]Total digestible nutrients (TDN); [9]Gross energy (GE); [10]Digestible energy (DE); [11]Metabolizable energy (ME).

Table 4. Comparison of food waste streams to common cattle and swine feedstuffs aggregating all nutrients in an absolute relative difference metric[1,2,3,4,5].

	Cattle			Swine		
Feedstuff	MS	VP	MX	MS	VP	MX
Alfalfa	9.48	3.92	7.23	10.09	4.08	7.53
Bakery Byproduct	**2.54**	3.19	**1.84**	4.72	4.72	3.74
Beet Pulp	7.69	2.91	5.81	9.83	3.65	6.76
Blood Plasma	—	—	—	6.27	7.57	6.37
Brome Hay	13.34	5.32	10.13	—	—	—
Cane Molasses	4.75	3.28	4.42	5.18	4.70	5.11
Citrus Pulp	4.65	**1.40**	3.36	5.52	**2.04**	4.25
Corn Gluten Feed	5.46	1.77	3.80	5.77	2.50	4.36
Corn Silage	7.81	2.46	5.88	—	—	—
Corn Stalks	13.88	5.40	10.45	—	—	—
Cottonseed Hulls	**21.39**	**10.93**	**17.56**	—	—	—
Cottonseed Meal	9.29	5.04	7.58	6.09	4.03	4.88
DDGS	6.52	4.94	4.99	5.99	4.69	4.34
Fish Meal	6.82	8.09	5.85	6.46	8.38	6.12
Grain Sorghum	2.69	2.46	2.91	3.73	2.63	3.12
Ground Corn	4.31	1.86	3.42	3.71	2.84	3.16
Hominy Feed	3.70	2.76	2.89	4.34	3.66	3.50
Oat Groats	—	—	—	3.34	3.30	2.72
Oats	5.17	1.97	3.86	6.12	2.90	4.81
Rice Bran	6.06	5.37	4.31	6.46	5.22	4.65
SBM, Dehull, Sol Ext	4.03	4.23	3.35	3.34	4.67	3.25
Soybean Hulls	10.30	3.36	7.47	11.43	4.77	8.62
Steam-flaked Corn	3.09	2.84	2.88	—	—	—
Wheat	3.16	2.36	2.58	**3.25**	2.46	**2.66**
Wheat Bran	7.18	2.20	5.35	6.92	2.98	5.27
Wheat Midds	6.66	1.96	4.91	7.53	2.90	5.74
Wheat Silage	10.57	3.02	7.74	—	—	—
Wheat Straw	14.34	6.08	10.84	—	—	—
Whole Cottonseed	9.02	8.41	6.71	**12.50**	**10.02**	**9.82**

Common feedstuffs values for cattle were sourced from the Nutrient Requirements of Beef Cattle: Eighth Revised Edition (National Academies of Science, Engineering, and Medicine, 2016). Common feedstuffs values for swine were sourced from the Nutrient Requirements of Swine: Eleventh Revised Edition (NRC, 2012). [1,2,3,4,5]The absolute relative difference between CP, ash, EE, NDF, lignin, TDN (cattle), and ME (swine) of the feedstuff and food waste stream were summed to give an aggregated relative difference for each food waste stream. Feedstuffs that are most similar to the respective food waste stream have the lowest value, feedstuffs that are the least similar have the highest value. Highest and lowest values per stream are in bold.

lignin (0.03 [MS] and 0.07 [MX] relative difference) and TDN (0.18 [MS] and 0.11 [MX] relative difference) were the two most compatible nutrients followed by ash (0.38 [MS] and 0.46 [MX] relative difference) and CP (0.39 [MS] and 0.36 [MX] relative difference). Ether extract of bakery by-product was only 0.60 relative difference for MS and 0.50 relative difference for MX. However, NDF relative difference was much greater in the bakery by-product than the MS and MX (0.95 and 0.35, respectively). On the other hand, the least compatible cattle feedstuff when compared to MS, VP, and MX waste streams was cottonseed hulls (aggregated relative difference of 21.39, 10.93, and 17.56, respectively). The two main factors contributing to the difference with cottonseed hulls were the NDF and lignin content. The NDF concentration of cottonseed hulls is 11, 3, and 7 times that of the MS, VP, and MX streams, respectively. Additionally, lignin was 9, 7, and 9 times greater than the MS, VP, and MX streams, respectively. Meanwhile, nutrients such as CP, TDN, EE, and ash were all less than 50% of their respective waste stream nutrient concentration with three exceptions: the ash concentration being 55% of the MS ash content, the TDN concentration being 56% of the VP TDN content, and the EE concentration being 72% of the VP EE content.

Other cattle feedstuffs that came comparatively close (less than +2 points from the lowest value mentioned above) for all three food waste streams were grain sorghum, hominy feed, steam-flaked corn, and wheat. Other feedstuffs that were comparable to VP but not MS or MX were corn gluten feed, corn silage, oats, and wheat bran and middlings, again, all less than +2 points from the value of citrus pulp. These feedstuffs had similar relative differences in TDN and EE concentrations to VP, with the exception of EE in oats.

The most compatible swine feedstuff for MS and MX streams was wheat (aggregated relative difference of 3.25 and 2.66, respectively). Of the nutrients, CP (0.25 [MS] and 0.20 [MX] relative difference) and ME (0.28 [MS] and 0.21 [MX] relative difference) were the two most compatible nutrients, followed by lignin (0.47 [MS] and 0.49 [MX] relative difference) and NDF (0.68 [MS] and 0.16 [MX] relative difference) which exceeded the MS and MX NDF content. The two least compatible nutrients of wheat were ash (0.66 [MS] and 0.70 [MX] relative difference) and EE (0.92 [MS] and 0.90 [MX] relative difference). On the other hand, the least compatible swine feedstuff was whole cottonseed for all three waste streams (aggregated relative difference of 12.50, 10.02, and 9.82 for MS, VP, and MX, respectively). The NDF content of whole cottonseed is 7, 2, and 5 times that of the NDF content of MS, VP, and MX waste streams, respectively. Additionally, lignin content of wheat is 5, 4, and 5 times that of lignin in the MS, VP, and MX waste streams, respectively. Crude protein of wheat exceeded all three waste streams (0.19 [MS], 0.69 [VP], and 0.25 [MX] relative difference). Ash (0.34 [MS], 0.54 [VP], and 0.42 [MX] relative difference), EE (0.30 [MS], 3.73 [VP], and 0.12 [MX] relative difference), and ME (0.30 [MS], 0.11 [VP], and 0.23 [MX] relative difference) content were all less than their respective food waste streams nutrient content with the exception of EE which was 4 times that of VP EE content and ME of VP (3207 vs. 2895 kcal/kg).

Additional swine feedstuffs worth noting that are similar, but not the closest, to all three waste streams, are grain sorghum, ground corn, and oat groats, all less than +1.5 from citrus pulp and wheat, as mentioned earlier. Soybean meal was a close comparison to the MS and MX streams, but not VP. Meanwhile, wheat, while not the most comparable to VP, was less than +0.5 from citrus pulp. Other feedstuffs that came very close in comparison to VP were wheat bran, wheat middlings, oats, and corn gluten feed, notably for the similarities in CP, EE, and ME.

4. Conclusion

In conclusion, this study evaluated food waste streams collected by like foods in order to determine the effect of collecting diverse food types separately or together on the nutrient profile. Day to day, there is a large range of nutrient concentrations that are possible, but when focusing on the amount of variation, it becomes more manageable. However, it seems that by keeping the streams separated by MS and VP, it either had no difference or decreased the standard deviation depending on the nutrient. Mainstream food waste was characteristic of high CP and energy, while VP was most characteristic of high fiber, specifically NDF and NDFn. This indicates that food waste could be potentially used as a viable feed alternative. More research needs to be done in terms of digestibility, palatability, and ingredient processing (moisture removal) to determine the optimal use of food waste.

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Conflicts of Interest

There are no conflicts of interest to disclose.

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