Recycled Cafeteria Food Waste as a Feed for Swine: Nutrient Content, Digestibility, Growth, and Meat Quality[1,2,3]

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ABSTRACT: This project was undertaken to compare growth, meat quality, and diet digestibility when pigs were fed cafeteria food waste (FW) or a corn/soybean meal (CSM) diet. Cafeteria food waste (36 samples) fed in the growing and finishing experiment averaged 22.4% DM, 21.4% CP, 14.1% ADF, 27.2% ether extract, and 3.2% ash. The first experiment used 50 crossbred pigs randomly assigned to four diets. During the growing phase, pigs fed a CSM diet gained faster ($P < .05$) than pigs fed FW or FW plus energy supplements. However, the two groups fed FW plus energy supplements (at 25 or 50% of the intake of the CSM diet) gained faster ($P < .05$) than pigs fed FW alone (.61 and .65 kg/d, respectively, vs .46 kg/d). In the finishing phase, FW plus an energy supplement fed at 50% of the level of CSM intake resulted in gains that did not differ from those of pigs fed the CSM diet (.90 vs .99 kg/d; $P > .05$). A nutrient digestibility and nitrogen balance trial using eight growing barrows compared FW with the same CSM growing diet fed earlier. Dry matter digestibility was similar for the two diets ($P > .05$). However, CP digestibility was higher ($P < .05$) in the FW diet than in the CSM diet (88.2 vs 84.3%). Although the percentage of nitrogen retained was not different between FW and CSM diets (56.0 vs 55.2%; $P > .05$), the amount of nitrogen retained was greater for pigs fed the CSM diet (29.3 vs. 24.5 g/d; $P < .05$) because DMI was greater (1.7 vs 1.4 kg/d) for pigs fed CSM compared with FW. At the completion of the finishing experiment, six pigs were selected from both the CSM and FW diets and fed to finishing weight. The pigs were slaughtered, and the pork loins were removed for flavor and texture analysis. A consumer panel rated the meat quality from FW pigs as acceptable and overall flavor comparable to CSM pigs ($P > .05$). These results indicate that food waste has nutritive value and may be useful in swine diets.

Key Words: Food Wastes, Pigs, Digestibility, Kitchen Wastes

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Introduction

Food waste (**FW**) can be described as any edible waste from food production, transportation, distribution, and consumption (Price et al., 1985). It is also referred to as garbage, swill, and(or) kitchen refuse (Kornegay et al., 1965). In addition, solid and liquid by-product wastes, are generated throughout the food production and processing sectors (CAST, 1995). In total, this may constitute as much as 20% of the total human food supply from the stage of processing to the point of consumption (Tolan, 1983).

Feeding FW to livestock is not a recent innovation. It has been practiced throughout the world and is often concentrated around metropolitan centers (Derr et al., 1988; Westendorf et al., 1996). In recent years, increasing requirements for environmental protection, resource preservation, and alternatives to landfill disposal of FW have made recycling of FW an attractive option.

The digestibility of FW in swine was found to be similar to that of a commercial swine diet (Kornegay et al., 1965). Most research on the nutritive value of FW was carried out over 30 yr ago (Heitman et al., 1956; Kornegay et al., 1965, 1968, 1970; Barth et al., 1966; McClure et al., 1970). Most recent reports have stressed the economic advantages of FW recycling (Price et al., 1985; Derr et al., 1988). Others have investigated the processing of FW, such as dehydration, pelleting, and(or) extrusion (Tadtiyant et al., 1989; Myer et al., 1994; Rivas et al., 1994; Goldstein,

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Table 1. Composition of diets (%)

Ingredient	Growing Diet A	Growing Diet B	Growing Diet C	Finishing Diet A	Finishing Diet B	Finishing Diet C
Finely ground corn	77.60	93.50	87.00	84.00	95.00	90.00
Soybean meal (48% CP)	19.20	.00	.00	13.50	.00	.00
Dicalcium phosphate	1.68	3.40	6.80	.97	1.94	3.88
Limestone	.97	2.00	4.00	.99	1.98	3.96
Salt	.25	.50	1.00	.24	.48	.96
Vit/Min. premix	.30[a]	.60[b]	1.20[c]	.30[a]	.60[b]	1.20[c]
CP, %	19.58	7.95	7.40	17.32	8.08	7.65
Calculated ME, kcal/kg	3,272	3,198	2,975	3,308	3,249	2,898

[a]Supplied the following amounts of trace minerals per kilogram of diet: Fe, 78 mg; Mn, .30 mg; Zn, 241 mg. Supplied the following amounts of vitamins per kilogram of diet: vitamin A, 17,000 IU; vitamin D_3, 4,145 IU; vitamin E, 98 IU; vitamin K, 6.2 mg; vitamin B_1, 83.2 μg; niacin, 83.5 mg; pantothenic acid, 62.6 mg; choline, 280 mg.

[b]Supplied the following amounts of trace minerals per kilogram of diet: Fe, 156 mg; Mn, .60 mg; Zn, 482 mg. Supplied the following amounts of vitamins per kilogram of diet: vitamin A, 34,000 IU; vitamin D_3, 8,290 IU; vitamin E, 196 IU; vitamin K, 12.4 mg; vitamin B_1, 166.4 μg; niacin, 167 mg; pantothenic acid, 125.2 mg; choline, 560 mg.

[c]Supplied the following amounts of trace minerals per kilogram of diet: Fe, 312 mg; Mn, 1.20 mg; Zn, 964 mg. Supplied the following amounts of vitamins per kilogram of diet: vitamin A, 68,000 IU; vitamin D_3, 16,580 IU; vitamin E, 392 IU; vitamin K, 24.8 mg; vitamin B_1, 332.8 μg; niacin, 334 mg; pantothenic acid, 250.4 mg; choline, 1,120 mg.

1995). This article describes a study of the nutritive value of present-day cafeteria FW and its feasibility for use as a source of feed when recycled in swine production. Four experiments were conducted to accomplish the following objectives: 1) to measure the nutrient composition of FW collected from a cafeteria; 2) to determine the feeding value of FW in swine feeding trials; 3) to characterize the nutrient digestibility of FW in growing swine; and 4) to evaluate the eating quality of meat collected from pigs fed FW.

Materials and Methods

Nutrient Composition, Experiment 1. Samples (n = 36) of cooked FW were randomly collected from individual barrels of FW at a student cafeteria on the Cook College, Rutgers University, New Brunswick, NJ campus. Barrels of FW were collected every 2 or 3 d, cooked thoroughly with steam for ~4 h at 100°C (U.S. Congress, 1980), and allowed to cool prior to feeding. These same barrels of cooked FW were fed to pigs in Exp. 2. All samples were immediately stored at –20°C for later analysis. The frozen samples were then thawed at room temperature and separately blended in an electric blender to create a homogeneous sample. After blending, the samples were oven-dried at 60°C to a constant weight to obtain a DM measurement, then ground through a 1-mm screen (Wiley Mill Standard No. 3, Arthur H. Thomas Co., Philadelphia, PA). After thorough mixing of the ground sample, a subsample was collected for nutrient analysis. Crude protein, ether extract (**EE**), and ash were analyzed using AOAC (1990) procedures. Prior to analysis, samples were dried in an oven at 100°C for 20 h, CP was analyzed with the Kjeldahl method using an automatic analyzer (Brinkmann Instruments Co., Westbury, NY), EE was measured with a soxtech system (Tecator, Herndon, VA), and ash was determined by igniting samples in a muffle furnace at 550°C for 8 h. Acid detergent fiber was measured with a fibertec system (Tecator, Herndon, VA) according to Goering and Van Soest (1975). Nitrogen-free extract (**NFE**) was calculated as 100 – CP% – ADF% – EE% – ash%. Minerals were determined by atomic absorption spectrophotometry (Perkin-Elmer 2380, Norwalk, CT). Data are presented as mean, standard deviation, range, and coefficient of variation.

Feeding Trial, Experiment 2. Growing pigs (26 male, 24 female, 29 ± 6 kg initial BW) were stratified by weight and sex and randomly assigned to dietary treatments. During the finishing phase, 40 pigs from the growing phase (20 male, 20 female, 59 ± 6 kg BW) were rerandomized and assigned to treatments. There was a 4-wk period between the growing and finishing periods during which all pigs received a corn/soybean meal (**CSM**) growing diet. Pigs were weighed every 2 wk throughout the experiment. The experimental procedure was approved by the Rutgers University Animal Care and Use Committee. Barrels of FW were collected and cooked as described in Exp. 1; extra barrels of cooked FW were stored at 4°C until feeding. Three grain diets (diet A, B, and C) were mixed for the growing and finishing phases; components of these diets are shown in Table 1. A similar design with four treatments was used for both phases: Treatment (**Trt**) 1 pigs received diet A, a CSM diet fed for ad libitum consumption, Trt 2 pigs received ad libitum access to FW plus diet B limited to 50% of Trt 1 intake of diet A, Trt 3 pigs received FW for ad libitum consumption plus diet C limited to 25% of Trt 1 intake of diet A, and Trt 4 pigs received ad libitum access to FW. These diets were formulated assuming that protein needs would be met by FW and that energy would be the limiting nutrient in FW diets. A vitamin/mineral premix (Agway, DeWitt, NY) was added to diets B and C at different levels to ensure that vitamin/mineral intake would be similar to the amount Trt 1 received from diet A. Treatments 2 and 3 were included to determine whether measured amounts of supplemental grain would result in improved performance.

This experiment was conducted in the swine feeding pens located at the swine farm at Rutgers, the State University of New Jersey. Treatment 1 pigs received diet A in self-feeders and Trt 2, 3, and 4 received FW and(or) diet B and C in metal hog-feeding troughs (NASCO, Janesville, WI). The growing phase lasted for 28 d. Prior to the growing and finishing phases, pigs were given access to their respective diets for 1 wk. Following the growing phase, pigs were placed on an ad libitum grower diet for several weeks and then rerandomized among treatments for the 42-d finishing phase. During the experiment, pigs in Trt 2, 3, and 4 were fed FW twice daily at 0800 and 1500, and pigs in Trt 1 were allowed ad libitum access to diet from self-feeders. Treatments 2 and 3 received added grain (diet B or C) once daily at 0800. Feed intake was measured in Trt 1 pigs weekly by measuring disappearance from self-feeders and the amount of grain fed to Trt 2 and 3 was adjusted accordingly. Treatments 2, 3, and 4 were given equal amounts of FW that were adjusted weekly based on the amount of wastage. Because of the high moisture content and the difficulty in collecting, no orts were collected for FW treatments. All pigs had free access to water.

There were four replicate pens ($n = 4$) per treatment in the growing phase and three replicate pens ($n = 3$) per treatment during the finishing phase. Data were analyzed (SAS, 1989) using a one-way ANOVA. When the main effect was significant ($P < .05$), means were separated using LSD multiple comparisons. Data were analyzed as pen within treatment, with pen serving as the experimental unit. Values are reported as least squares means.

Nutrient digestibility, Experiment 3. Eight growing barrows (35.4 ± 5.1 kg) received either FW or a CSM diet. The FW used was collected separately from that collected and used in Exp. 1 and 2, but the CSM diet was the same grower diet used in Exp. 2 (see Diet A in Table 1). Animals were maintained in metabolism cages for 15 d (10 d of adaptation and 5 d of collection). This experiment was conducted in two periods, with two pigs per treatment in each period. The experimental procedure in this experiment was approved by the Rutgers University Animal Care and Use Committee.

Two barrels (350 kg) of FW were collected and cooked as described in Exp. 1. After thorough mixing, FW was transferred to storage containers, sampled, and frozen at –20°C for later use and analysis. Both diets were analyzed for nutrient content as described in Exp. 1.

Pigs were fed twice daily at 0800 and 1700 h with free access to water from a measurable water container. Considering the high moisture content in FW, water was added to the CSM diet in a 1:1 ratio at each feeding. During the adaptation phase (10 d), feed intake was monitored and adjusted so that all pigs consumed 90 to 95% of the diet offered. During the 5-d collection phase, feed intake of each pig was measured daily. Feces and urine were collected twice a day and frozen at –20°C. Feces from the five consecutive collection days were pooled for each pig for chemical analysis. Loss of ammonia from the urine due to volatilization was prevented by adding 50% sulfuric acid to the plastic urine container at 1.5% of urine volume. Urine production from each pig was measured and subsampled for nitrogen analysis.

Pooled fecal samples were analyzed for nutrient content as described for FW in Exp. 1. Urine samples were thawed at room temperature for 24 h prior to nitrogen analysis (Kjeldahl). Samples were analyzed for amino acid content by HPLC. Data were analyzed as a 2×2 factorial with diet and period as cofactors. Period was not significant, so all data were pooled and analyzed with a *t*-test (SAS, 1989). Significant differences were declared if $P < .05$.

Taste Test, Experiment 4. At the completion of Exp. 2, 12 pigs (six from Trt 1 and six from Trt 4) remained on the experimental diets until a finishing weight of 110 kg was reached. They were then slaughtered, and loins were collected and stored at –20°C for later palatability testing.

A total of 65 people were recruited and participated on a consumer panel. The panel included faculty, staff, and students at Rutgers, The State University of New Jersey recruited through a leaflet advertisement. The taste panel was administered, and results were analyzed using a computerized sensory analysis program at the Rutgers University Department of Food Science. The panel was run from 1000 to 1530 on November 28, 1995. Groups of people (maximum of nine at a time) were seated in individual booths equipped with a computer monitor. Each member of the panel was given a registration number and instructed on how to enter responses and signal the attendant. Each person tasted two pork meat samples, one from each experimental group and without knowledge of origin.

On the test day, the pork samples were thawed and placed into cold storage (4°C) prior to cooking. The chops were placed on racks in shallow baking trays and baked at 350°C until an internal temperature of 68.3°C was reached. The cooking time varied with the

Table 2. Nutrient composition of cooked food waste (FW) taken from a student cafeteria

Nutrient[a]	Mean ± SD	Range	CV
DM	22.38 ± 6.73	10.62–34.69	30.1
	% DM		
CP	21.36 ± 4.27	8.81–29.45	20.0
ADF	14.12 ± 10.46	1.17–30.34	74.1
Ether Extract	27.15 ± 12.83	10.87–57.63	47.3
Ash	3.20 ± 1.13	1.50–6.40	35.3
Ca	.49 ± 0.39	.04–1.76	79.6
P	.58 ± 0.47	.21–2.85	81.0
Mg	.19 ± 0.21	.03–1.05	110.5
K	.63 ± 0.44	.27–2.15	69.8
Na	1.20 ± 0.84	.14–3.84	70.0
	ppm		
Fe	157.17 ± 96.79	21.23–407.92	61.6
Cu	31.13 ± 31.23	2.43–112.25	100.3
Zn	68.90 ± 50.09	11.33–126.00	72.7
Mn	40.12 ± 35.30	5.98–112.90	88.0

[a](n = 36 samples).

amount of pork meat in the ovens, but, on average, they were baked for 40 min and were turned at 20 min. The cooked meat was then transferred to two separate cutting boards and cut into 3.8-cm cubes. The pork cubes were immediately placed into covered souffle-cups labeled with three-digit random numbers. The samples were evaluated within 1 h after being placed in the cups.

Pork was evaluated for three attributes (flavor, chewiness, and juiciness) and rated for intensity and preference, also referred to as liking, using a 15-cm line scale (scores from 1 to 15). Panelists also rated two overall preference questions for flavor and texture. Higher preference scores indicate greater liking. Higher or lower intensity scores indicate the degree of intensity of the individual attribute (flavor, chewiness, and juiciness). Each person received both pork samples with the presentation order randomized across panelists. The panelists answered all the questions about one sample before moving to the next sample. They could only move forward in the computerized ballot and could not change their previous answers. This test is a standardized method of comparing samples (Meilgaard et al., 1991). All data were pooled and analyzed with a *t*-test (Snedecor and Cochran, 1980) with differences between mean values declared significant at $P < .05$.

Results

Nutrient Composition, Experiment 1. Nutrient composition of FW was highly variable, as indicated by high CV values and wide ranges (Table 2). This was particularly true for fiber, EE, and ash, although some individual minerals had CV near 100%. Concentrations of minerals, although variable, were generally sufficient when compared to NRC standards (1988). Iron levels tended to be high but were still within a safe range (NRC, 1980). The crude protein content of the food waste was > 21% on a DM basis. The protein content was similar to that in dehydrated restaurant waste as reported by Myer et al. (1994).

Feeding Trial, Experiment 2. During the growing phase, the CSM-fed group gained significantly more than the three groups fed FW and FW plus supplement (Figure 1). Pigs fed FW alone gained significantly less than all other groups. No significant differences existed between the two supplemented groups (Trt 2 and 3). Supplementing FW with grain significantly improved the performance of pigs when compared with the FW only group, but performance was still poorer than Trt 1 ($P < .05$). During d 15 to 28, significant differences in body weight gain were observed only between Trt 1 and 4. The different patterns of body weight gain between d 0 to 14 and d

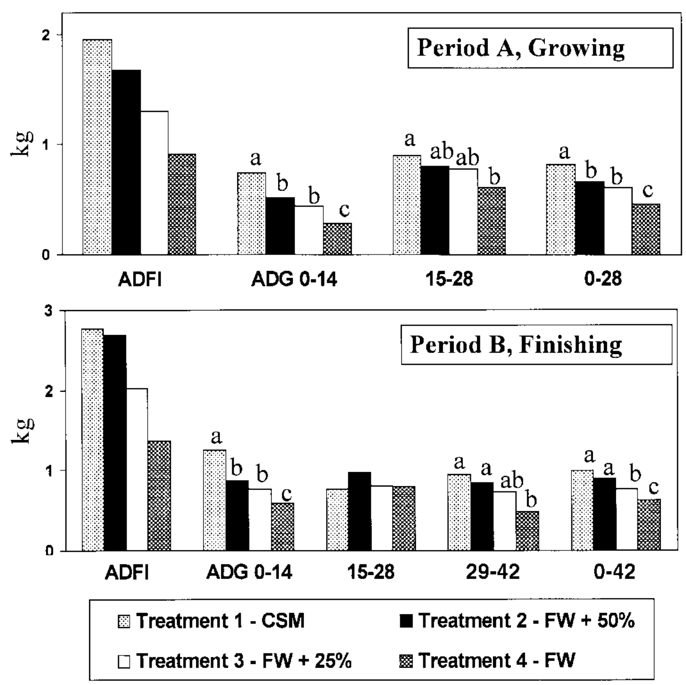

Figure 1. The ADFI and ADG of pigs fed either food waste (FW) or a corn/soybean meal (CSM) diet. Any bars with a letter in common were not significantly different, otherwise different at $P < .05$. Growing period (A) standard errors for the different measurements were ADG 0 to 14 = .048, ADG 15 to 28 = .054, and ADG 0 to 28 = .043. Finishing period (B) standard errors were ADG 0 to 14 = .034, ADG 15 to 28 = .086, ADG 29 to 42 = .089, and ADG 0 to 42 = .036. Treatments were as follows: 1, diet A, CSM fed for ad libitum consumption; 2, FW fed for ad libitum consumption plus diet B fed at 50% of Treatment 1 intake; 3, ad libitum access to FW diet C fed at 25% of Treatment 1 intake; and, 4, FW fed for ad libitum consumption.

Table 3. Nutrient digestibility and daily nitrogen balance of a food waste (FW) and a corn/soybean meal (CSM) diet

Nutrient	FW	CSM	SE
DM, %	86.69	85.60	.48
CP, %	88.16[a]	84.29[b]	.80
ADF, %	53.71[a]	70.58[b]	1.75
Ether extract, %	93.51[a]	27.62[b]	1.50
Ash, %	77.09[a]	62.53[b]	.93
NFE, %	97.22[a]	93.77[b]	.65
Nitrogen			
Intake, g	44.05	53.19	2.68
Excretion, g	19.51	23.93	2.06
Balance, g	24.54[a]	29.26[b]	1.06
Retention, %	55.96	55.22	2.10
Amino acid digestibility, %	91.0[a]	86.6[b]	.008

[a,b]Values in the same row were significantly different at $P < .05$.

15 to 28 may indicate that pigs were adjusting to the large volume of food waste they received. Despite the 1-wk adaptation period prior to beginning the growing phase, it was only during the final 2 wk of the period when gains in Trt 4 increased to greater than .60 kg/d. During the 28 d of the study, results followed the same pattern as the first 14 d.

Figure 1 also presents body weight gains of pigs during the finishing phase. During d 0 to 14, the average body weight gain of pigs differed significantly among the treatments. The CSM-fed group (Trt 1) gained the most, the food waste group (Trt 4) gained the least, and the supplemented groups gained intermediate amounts. During d 15 to 28, all groups grew similarly, and Trt 4 performance was the greatest seen for any 2-wk period (.79 kg/d) during the experiment. During d 29 to 42, Trt 4 pigs gained significantly less than pigs in Trt 1 or 2, but not Trt 3 ($P > .05$). Throughout the entire finishing phase Trt 2 performed as well as Trt 1 ($P > .05$) and gained significantly more than the other treatments.

Dry matter intakes for all FW pigs (Trt 2, 3, and 4) in the growing phase averaged .92 kg/d of FW (DMI), and the CSM-fed pigs (Trt 1) averaged 1.96 kg/d of DMI. Treatment 2 pigs received .76 kg of grain/d, and Trt 3 pigs received .38 kg of grain/d. In the finishing phase, all FW pigs (Trt 2, 3, and 4) averaged 1.36 kg/d of FW (DMI), and the CSM-fed pigs (Trt 1) averaged 2.77 kg/d of DMI. Treatment 2 pigs received 1.33 kg of grain/d, and Trt 3 pigs received .67 kg of grain/d during the finishing phase. Because it was difficult to accurately measure the intake of FW, feed consumption figures (except for CSM—Trt 1) are only estimates. Figure 1 gives ADFI for the growing (0 to 28 d) and finishing (0 to 42 d) periods for comparison with ADG values.

Nutrient Digestibility, Experiment 3. The FW used in Exp. 3 had the following analysis: DM = 22.0%, CP = 20.2%, ADF = 15.2%, EE = 29.0%, ash = 3.7%, and NFE = 31.9%. These results are similar to those for the FW used in Exp. 1 and 2. Food waste-fed pigs consumed 1,360 ± 173 g/d (DMI), and pigs fed CSM consumed 1,698 ± 163 g/d ($P < .05$; SE = 84.2; DMI). Nutrient digestibility and nitrogen balance data were calculated and are presented in Table 3. The DM digestibility was not significantly different between the FW and CSM diets. The ADF digestibility of FW was lower ($P < .05$) than that of the CSM diet, and the digestibility of CP, EE, ash, and NFE was higher ($P < .05$) in FW than in the CSM diet. Nitrogen balance of the FW diet was significantly lower than that of the CSM diet. This is likely due to greater DMI and greater total nitrogen intake in the CSM-fed pigs. The percentage of nitrogen retained did not differ significantly between the two groups. Amino acid digestibility was greater in pigs fed FW (Table 3). The amino acid content of FW was also greater than that of the CSM diet (Table 4).

Because FW has a high moisture content, water intake, excretion, and balance were also measured in this experiment (Table 5). Dietary water intake was significantly greater in the FW- than in the CSM-fed group. However, pigs fed FW drank significantly less water than pigs fed the CSM diet, so total intake was not different. Urine and total water excretion of the FW group were significantly greater than those of the CSM-fed pigs. There were no significant differences in water balance between the two groups, indicating the ability of the pigs to regulate their water balance regardless of dietary water content.

Taste Test, Experiment 4. Taste intensity ratings for all three attributes measured in the taste test were different for meat from FW- or CSM-fed pigs (Table 6). Pork loins from FW-fed pigs had a stronger flavor and were less chewy and more juicy than the pork from CSM-fed pigs. Mean scores for preference or liking of chewiness and juiciness also differed signifi-

Table 4. Amino acid content of food waste (FW) and corn soybean/meal (CSM) diets fed in Experiment 3

Amino acid	FW	CSM
	% DM	
Histidine	.52	.43
Arginine	1.05	1.06
Threonine	.78	.63
Valine	.92	.75
Methionine	.33	.17
Isoleucine	.80	.65
Leucine	1.40	1.42
Phenylalanine plus		
Tyrosine	3.04	2.15
Lysine	1.03	.72
Aspartate	1.41	1.48
Glutamate	3.36	2.91
Serine	.9	.85
Glycine	.69	.66
Alanine	.83	.92
Proline	1.36	1.14
Total amino acids	18.50	16.02

Table 5. Daily water intake and excretion of pigs fed either food waste (FW) or corn soybean/meal (CSM) in Experiment 3

Item	FW	CSM	SE
Water intake			
Dietary	4.83[a]	2.16[b]	.230
Drinking	.21[a]	1.63[b]	.239
Total	5.04	3.78	.385
Water excretion			
Urinary	2.31[a]	1.09[b]	.247
Fecal	.47	.49	.042
Total	2.78[a]	1.58[b]	.281
Water balance	2.26	2.20	.151

[a,b]Values in the same row were significantly different at $P < .05$.

cantly between the two groups, but there were no differences in flavor preference. Pork from FW-fed pigs was preferred or liked more for its chewiness and juiciness rather than its flavor. Overall preference scores for texture were significantly greater for pork from FW-fed pigs. Scores for overall flavor preference were not significantly different between the two treatments.

Discussion

Results of these experiments support the hypothesis that the nutrient digestibility of FW fed to pigs is not less than a standard CSM diet. Digestibility of FW, therefore, should not be a limiting factor for FW recycling. Most nutrients in FW had a digestibility similar to or greater than that of the CSM diet, with ADF being the exception. A higher ADF content in FW may decrease its efficiency for digestion and its digestibility. High fiber levels in the cafeteria FW used here may be the result of the cafeteria practice of mixing paper (napkins) with FW. These results also demonstrated that FW contained a higher level of EE than the CSM diet and that the digestibility of EE was significantly higher for FW-fed pigs than for the CSM-fed pigs. This result may be due to different compositions of EE in the FW and in the CSM diet. The EE in the FW was likely from true lipids, and the EE in the CSM diet was possibly composed of more pigments and might have been cell wall bound, which would decrease its efficiency for digestion.

Results of nutrient analysis indicate that the low DM content of FW might represent the largest problem in feeding FW to swine. Food waste has a DM content approximately 25% that of a more traditional corn and soybean meal diet. This means that pigs must consume nearly four times the volume of FW to obtain the same amount of DM. The crude protein content of FW (> 21%) supports the earlier contention that CP would not be the limiting nutrient in FW-fed pigs in Exp. 2. If consumption is sufficient, crude protein requirements should be satisfied. On a DM basis, it is unclear whether FW would supply adequate energy, although the high EE (> 27%) indicates that it may. This high lipid content could influence energy and protein relationships in the diet and may influence the composition of gain as well. However, because food waste was fed wet, it became necessary to supplement extra energy in the form of added grain to attain rates of gain equal to CSM-fed pigs. Although variable, these results are in general agreement with previous reports (Kornegay et al., 1965, 1968), with the exception that the ash level in this experiment was lower than that in previous reports. This lower ash may have been caused by the exclusion of bone waste from FW samples in this experiment. In previous research (Kornegay et al., 1965, 1968), samples were collected over several years and nutrient content was variable but relatively consistent within source. The cafeteria collections described here were a short-time analysis and indicate that, in the short-term, FW is highly variable in nutrient composition.

In the growing and the finishing phases, the CSM-fed pigs performed better than all other treatments, and the 100% FW-fed pigs gained the least. Supplementing FW with grain improved body weight gain during both periods. In the growing phase, there were

Table 6. Mean ratings for intensity and preference (liking) for pork taste of pigs fed either food waste (FW) or corn soybean/meal (CSM)[a]

	Intensity			Preference		
Attributes	FW	CSM	SE	FW	CSM	SE
Pork flavor	7.65[b]	6.61[c]	.44	7.13	7.09	.46
Chewiness	7.65[d]	8.97[e]	.37	8.97[d]	7.26[e]	.43
Juiciness	9.03[d]	6.49[e]	.43	8.95[d]	6.82[e]	.44
				Overall preference		
Flavor				7.21	6.70	.46
Texture				8.46[b]	7.42[e]	.44

[a]Values are reported as 1 to 15 on a 15-cm line scale.
[b,c]Values in the same row were significantly different at $P = .05$.
[d,e]Values in the same row were significantly different at $P < .05$.

no differences in gain between pigs fed FW supplemented with 25 or 50% grain; however, in the finishing phase, pigs receiving 50% grain supplementation performed as well as those receiving 100% CSM. These results re-emphasize previous work done by Kornegay and colleagues (1970), who found that adding grain to the diets of pigs fed FW resulted in improved swine performance regardless of FW source or quality.

It was also observed in Exp. 3 that the pigs coped with the high moisture content of FW by drinking less water and excreting more urine. Nutrient digestibility was not greatly affected by the high moisture content of FW. This result agrees with that of Kornegay and Vander Noot (1968), who reported that the water content of a diet does not negatively influence the digestibility of the diet. Nevertheless, these results and those of Kornegay and Vander Noot (1968) indicate that water content may decrease DMI. Experiments 2 and 3 demonstrated a reduced DMI when FW was the sole feedstuff. This underscores the need for new ways of processing FW, other than the traditional wet cooking, to reduce moisture content and cook the product without destroying nutrients.

An interesting observation from Exp. 2, Period B, is presented in Figure 1. During d 15 to 28, there were no differences in gain, because FW-fed pigs grew slightly faster than the CSM-fed pigs (.79 vs .76 kg/d, respectively). Food waste-fed pigs may have been compensating at this time as they became adapted to FW. Kornegay and Vander Noot (1968) found that, over a range of diets containing 10 to 85% moisture, the DMI and ADG increased as adaptation time increased. The ADG in animals fed 85% moisture feed more than doubled in the second 28 d of a 56-d feeding trial. The greatest adaptation effects in gain and feed efficiency occurred in animals receiving 85% moisture feed, because the increases were much smaller with lower moisture percentages in the feed. Another study by Kornegay et al. (1970) showed that rats fed garbage also adapted as feeding time increased. It is likely that compensatory growth (Pond et al., 1995) was occurring during this period, because animals offset a previous restriction in nutrition with greater growth during the second 14 d.

Although the total nitrogen retained (Exp. 3) in the FW group was lower than in the CSM-fed group, the percentage of nitrogen retained was not different. Lower DMI and nitrogen intake in pigs fed FW was likely the major cause of this decrease in nitrogen retention. Results from amino acid analysis are not consistent with the CP values presented for the grower diet and FW used in Exp. 3 and may highlight differences in nonprotein nitrogen content of the diets. Essential amino acid content was greater in the FW diet and compares reasonably well with that required for a growing pig as described by the NRC (1988). Food waste may contain some meat, meat by-products, and milk products such as cheese. The animal products present in FW may contribute to the amino acid profile observed.

Despite the lower DMI seen in FW-fed pigs, the quality of protein is at least comparable to that in CSM-fed pigs. Kornegay et al. (1968) determined nitrogen balance and percentage retention when pigs were fed several different types of FW. Nitrogen balance and retention were similar when hotel/restaurant, institutional, and military FW were fed. However, when municipal FW was fed, nitrogen balance and percentage retention were reduced considerably. Recent research by Myer et al. (1994) and Rivas et al. (1994) with a dehydrated FW product showed that the protein present could be utilized by a pig when percentages up to 20% were incorporated in the diet. Crude protein digestibility was reduced, and there was a lower pepsin digestibility and lower lysine availability in the dehydrated product. The authors concluded that overcooking during the dehydration process may have caused this reduction. Any new processing techniques for food waste must also minimize any nutrient losses such as might be caused by cooking.

The taste test experiment determined that the quality of pork meat from the FW group was not lower than that from the CSM diet and for some attributes was higher. Composition of gain may have had some influence on these taste characteristics. The average slaughter and carcass weights for CSM-fed pigs were 108 ± 7.3 and 71 ± 2.5 kg and for FW-fed pigs were 101 ± 8.9 and 66 ± 7.7 kg, respectively. It is possible that the higher fat of the FW diet resulted in greater adipose tissue accretion in the loin chops and influenced taste quality. There was no determination of lipid content or profile made in any of the samples. Previous research has indicated that carcass quality of pigs receiving FW is similar to that of pigs receiving more traditional diets (Peterson, 1967; Kornegay et al., 1970).

This research confirms that FW does have nutritional value as indicated by the overall nutrient profile, digestibility, and protein quality and that meat from FW-fed pigs may be of adequate quality, as scored by a consumer taste panel. The chief drawback from FW is the high moisture content, resulting in a decline in DMI in pigs. In addition to the negative influence on DMI, FW has other drawbacks, including the need for cooking to meet the requirements of the Swine Health Protection Act (U.S. Congress, 1980), the difficulty in handling and storage, and the need for appropriate management. Based on the research and discussion presented here, the following suggestions are proposed for use of FW in swine production and for research in this field: 1) FW should be supplemented if pigs are to achieve optimum performance; 2) if FW is to continue to be fed wet, then improved and appropriate management systems must be developed;

and, 3) improved processing techniques for FW such as dehydration, pelleting, and extrusion may decrease some of the negative aspects (Westendorf et al., 1996).

Implications

Food waste has excellent nutritional quality as indicated by nutrient analysis, digestibility, and protein availability and quality. The high moisture content in food waste reduces dry matter and nutrient intake, and it is the major constraint for use of food waste. New means of processing food waste must focus on maintaining the nutritive quality of food waste while reducing its high moisture content.

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