THE COMPOSITION, DIGESTIBILITY, AND
ENERGY EVALUATION OF FOOD WASTE
PRODUCTS FOR SWINE IN HAWAII

BY

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M.S. THESIS IN ANIMAL SCIENCE

We certify that we have read this thesis and that in our opinion it is satisfactory in scope and quality as a thesis for a degree of Master of Science in Animal Science.

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TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

In Hawaii garbage is one of the major sources of feed for swine. This can be attributed in part to the preference by the local population for the "soft carcass," which is characteristic of swine finished on garbage.

Hawaiian pork, besides being dressed differently from the mainland U.S.A. style, is marketed as a fresh "hot" product rather than being chilled. The reason for this is custom and to the different types of dishes prepared by the large oriental population in the islands. This "hot," soft pork will bring a premium price well above the hard, chilled carcases. The demand for this specialized pork product, which is developed primarily by garbage feeding, can be expected to remain constant.

Another reason for the use of garbage as a feed centers around the economics of Hawaii's swine production. Most hog farms in the islands are maintained as a family unit. Although specialized, and in some cases very efficient, the lack of capital often prohibits the change from garbage feeding to the more expensive imported grain rations. Garbage feeding requires an abundance of labor to collect and cook the material. Although establishments are paid for the privilege of removing their garbage, the monetary output by the producer for the labor involved is small since the family members usually carry out most of the operation.

Oahu, the most populated island in the state, contains the major portion of hog farms that feed garbage. This is due to the large supplies of garbage which can be obtained from the military complex and tourist related industries.

Although Hawaii ranks sixth nationally in the number of swine that are fed garbage, the latest island study dealing with the composition of this material was conducted over 20 years ago. Changes in eating habits and food processing techniques along with the advent of large scale tourism have undoubtedly changed the composition of garbage. Also the collection procedure has changed in that the use of residential garbage has almost disappeared. Today, water content may play an important factor since large additions are usually made by the producer to facilitate cooking. Because Hawaii's garbage is fed as a mixture from various sources, it would seem logical to examine the material as it is found in cookers at the various farms.

Realizing that changes in the composition of garbage in Hawaii have taken place and that a thorough analysis was never conducted on this material, this research was conducted to determine the complete chemical composition, digestibility and energy content of the garbage being fed on hog farms in Hawaii. Complete data of this type is essential for determining supplemental needs or other improvements in feeding practices. Another objective of this study was to determine the exact fatty acid composition of garbage fat.

REVIEW OF LITERATURE

GARBAGE AS A FEED FOR SWINE

The use of garbage, commonly known as food waste products, kitchen refuse, swill or slop, as a feed for swine is widespread throughout the world and is certainly not a new concept. The conversion of any inedible or discarded food materials into pork can be considered a sound and economical procedure providing the cost of collection does not become prohibitive.

The method of processing garbage before it is fed has varied between localities. During World War II, England maintained a processing plant where food waste was dried to a thick paste, bagged and shipped to various parts of the country. Water was added before feeding to swine (Woodman and Evans, 1942.)

All of America's states now have laws requiring that garbage used for feeding swine be brought to a high internal temperature for a specified period of time. Hawaii requires 30 minutes of cooking at 212°F. followed by a slow cooling period (Board of Health, State of Hawaii). This procedure is carried out to destroy infectious material and help curb the spread of trichinosis and vesicular exanthema.

Water is sometimes added to facilitate cooking and would naturally dilute the nutrients that the hog received. The use of steam injection cookers by some producers eliminates the need to add water since the hot steam rises through the material from pipes in the bottom of the cooker.

In Hawaii some garbage feeders skim off part of the hot fat layer that rises to the top of the cooking tank. This excessive fat is thought to produce digestive upsets and sanitation problems.

In previous studies the composition of garbage varied with the source sampled and from season to season (Kornegay et al., 1965). Garbage composition did not vary significantly between the days of the week (Engel et al., 1957; Kornegay et al., 1965). The common sources tested were designated as military, institutional, hotel and restaurant, and municipal. Military garbage was more desirable than that from other sources (Woodman and Evans, 1942; Henke et al., 1948; Kornegay et al., 1965). Engel et al. (1957) reported garbage composition to vary between farms.

Although most reports on garbage present their data on a dry matter basis, in actual practice it is usually not fed in this form. A review of the literature shows that the research work carried out on garbage and its digestibility by swine has been limited.

NUTRITIVE COMPOSITION OF GARBAGE

Moisture Content

The first limiting factor in garbage as a feed for swine is the high moisture content. Reported values range from 70 percent to as high as 90 percent water, whereas grain rations usually contain not more than 20 percent. Difficulty is encountered with high moisture rations in that the animal cannot consume a sufficient quantity of the material to meet its nutritive requirements. This is especially important when growing pigs are being fed. It has been calculated that 100 pound pigs would have to consume 29 pound of hotel and restaurant garbage having 84 percent moisture, 28 pound of institutional garbage (82 percent moisture), 17 pound of military garbage (74 percent moisture) or 24 pound of municipal garbage (83 percent moisture) daily to meet their protein requirements (Kornegay, 1965). Similar data has been calculated for various weight classes of pigs concerning gross energy and essential minerals by Kornegay (1965). These data show that large amounts of garbage must be consumed to meet daily nutrient requirements.

Differences in water content between sources of garbage have been noted by many workers. Thomas and Hargrave (1931) in England found hotel swill to have considerably more moisture (76.5 percent) than restaurant material (69.6 percent). Some of the artificially dried commercial swill products in England were comparable to grain feeds for swine. One such product was reported by Woodman (1941 a) to have a moisture content of only 10.2 percent. Fishwick (1941) stated that the most important factor determining swill quality was the amount of water added for cooking. In an extensive English study concerning garbage, Woodman and Evans (1942) compared the composition of military swill, processed urban swill and a commercially dried balanced swill. On a fresh basis the moisture content of the military and urban materials were almost identical, having values of 68.6 percent and 68.1 percent, respectively. More recent workers (Engel et al., 1957) found garbage in Virginia, U.S.A., to be only slightly variable due to source (hotel-restaurant 82.8 percent, household 83.4 percent and military 78.2 percent). Kornegay in 1965 reported similar results with military garbage being the lowest at 74.3 percent, institutional 82.3 percent, municipal 83.4 percent and hotel and restaurant containing 84.0 percent water. Kornegay <u>et al.</u> (1965) also found military garbage to be lower in moisture ($P < .01$) than the other sources tested. However, they found no difference between seasons of the year or days of the week.

In 1943 a study by Work <u>et al.</u> tested Hawaii's garbage from the University cafeteria and a local army base. The former source contained 72.3 percent water while the latter 69.6 percent. Hawaii's most recent garbage study by Willett <u>et al.</u> in 1948 dealt almost entirely with military garbage. Moisture percentages from over 130 samples per year were averaged for each year from 1942 to 1945. An average for the four years gave a value of 69.9 percent for 622 samples. This data did not vary greatly from that reported in previous years by other workers in the U.S.A. and England.

<u>Protein Content</u>

Thomas and Hargrave (1931) sampled both hotel and restaurant swill over an 18-week period. On a dry matter basis the hotel garbage ranked higher in crude protein than the restaurant material (25.2 percent vs. 17.1 percent). Woodman (1941 a) found dried swill collected during the summer to contain 24.8 percent crude protein. He noted that no supplementation would have to be made with this high protein material. In another study conducted on swill collected in winter, Woodman (1941 b) found protein content to be considerably lower (14.7 percent). He attributed this to large increases in potato peelings and vegetable material present during the winter months. In 1942 he compared the winter dried swill product with the average of 16 samples of military swill. Military swill ranked considerably higher in protein content at 20.4 percent.

Engel *et al.* (1957) examined garbage from four major sources and reported protein variation to be nonsignificant. Differences in protein level on different days of the week were reported by Kornegay *et al.* (1965) to be not significant, but differences ($P < .05$) did exist between seasons. The garbage had higher protein values during winter and spring (16.2 percent and 16.3 percent) than during summer and fall (14.2 percent and 14.5 percent). This is the opposite of that reported by Woodman (1941 a and b). His major sources sampled ranged from 13.9 percent to 17.5 percent protein. These observations agreed with the earlier work of Engel *et al.* (1957).

Early studies in Hawaii by Work (1943) reported army garbage to be relatively high in protein with an average of 22.4 percent for 96 samples. Twenty-three samples taken from the University cafeteria had an average value of 18.5 percent protein. Later sampling by Willett *et al.* (1948) showed army garbage to be higher in protein than the local cafeteria material (21.5 percent vs. 16.1 percent).

Crude Fiber Content

Since fiber is a limiting factor for monogastric animals, the amount present in garbage greatly affects efficiency and the daily gain that can be made by pigs. A visual inspection of most swill reveals an abundance of vegetable wastes. However, most literature does not indicate that these wastes result in an excessively high fiber level being present in the overall material. Paper, coffee grounds and other foreign matter, present to some degree in all garbage, also contribute to the fiber content.

Thomas and Hargrave's (1931) investigation of hotel and restaurant kitchen refuse reported a mean value of 2.1 percent crude fiber. In what they termed "first-class" and "second-class" cafes (defined by the authors as places frequented by middle class and working people in Britain) the fiber content was reported to be 3.3 percent. They attributed this difference to larger amounts of vegetable material present.

Woodman (1941 a) reported that swill collected during summer had a higher fiber level (7.8 percent) than his (1941 b) winter collection (5.8 percent). He observed that more vegetable matter seemed to be present during the winter months. In a more comprehensive study Woodman and Evans (1942) found military material to be lower in fiber than any of the other sources investigated. He felt this material could not be fed with good results since it contained only 1.6 percent fiber. He recommended that it be fed in conjunction with middling or other bulky feeds to prevent constipation.

Engel _et al._ (1965) also reported military garbage to be lower ($P < .05$) in fiber than other sources sampled. He also found a higher ($P < .05$) amount of fiber present in all sources during the spring and summer than in the winter and fall. An average of all sources gave a value of 5.2 percent fiber. The highest amount found was 7.2 percent which was in household waste. Engel _et al._ (1957) suggested that this high level of fiber for dry material was approaching the upper permissible limits, especially for younger pigs.

Kornegay et al. (1965) found crude fiber to be higher ($P < .05$) in garbage collected during the summer than other seasons, but no difference was found in fiber content for day of the week collected. Comparisons between major sources revealed municipal garbage to be significantly higher in fiber with a value of 8.4 percent.

The Hawaii study by Willett et al. (1948) showed military garbage to have a relatively low mean fiber content of 2.0 percent. University cafeteria waste averaged 3.2 percent fiber. These data agree with earlier work which showed military material to be lower in fiber than other sources tested.

Nitrogen Free Extract Content

Because of the abundance of carbohydrates in human diets, N.F.E. is usually the largest component present in garbage material. Early work by Thomas and Hargrave (1931) reported N.F.E. values ranging from 40.8 percent to 56.7 percent for hotel, restaurant and cafe food waste. In another paper, Miller (1934) used municipal garbage having a carbohydrate value of 41.8 percent as a supplement in a swine feeding trial. Woodman (1941 a) reported municipal swill collected during the summer to contain 29.8 percent carbohydrate. Winter collections averaged 57.9 percent thus revealing a large seasonal variation for this component. Engel et al. in 1957 also found this seasonal difference for N.F.E. In addition, major sources of garbage sampled were found to vary significantly ($P < .01$). Values ranged from a low of 40.4 percent N.F.E. for household garbage to a high of 49.9 percent for both hospital and hotel-restaurant garbage. The overall mean of all sources sampled was 44.7 percent. Kornegay et al. (1965) did not find a seasonal difference for N.F.E. in New Jersey's garbage. However, institutional garbage was higher ($P < .01$) in N.F.E. than other sources sampled.

Early reports in Hawaii by Work et al. (1943) showed University garbage to be higher in N.F.E. (44.7 percent) than military material (38.5 percent). In 1948 Willett et al. confirmed this earlier work by showing the University garbage to average 44.4 percent N.F.E. and military to have 41.2 percent. These means were based on large sample numbers (622 over a period of 4 years) and therefore these values were very reliable.

Mineral Composition and Ash Content

Most studies of garbage reported in the literature give ash values, however, comparatively few workers have analyzed this ash for the amount of important macro or micro minerals present. In dealing with mineral nutrition one must keep in mind proportions present as well as total content. The importance of the calcium/phosphorus ratio and its effect on other elements is well known.

Undoubtedly bones contribute to high ash values of garbage. Small bones become soft during cooking and will be consumed by pigs thus contributing to the nutritive value of the garbage. Large bones which do not soften are of little value and a possible nuisance.

Thomas and Hargrave in 1931 reported a high variation in ash content of garbage. They found cafe swill to have a 9.8 percent ash content which was much greater than hotel, restaurant or some of the other cafe wastes. They felt this high value might be explained by small soil particles present on large amounts of potato skins. These potatoes were not washed before peeling.

Woodman and Evans (1942) reported that a commercially dried swill product in England had a higher ash content than either processed urban or military camp swill. This was due to the addition of fish bones during manufacturing (18.3 percent vs. 9.8 percent and 6.0 percent respectively). Their analysis also included chlorine and from its value they concluded that NaCl was adequate in the garbage sources sampled. Lime (CaO) and phosphoric acid (P_2O_5) values were also given as indicators of calcium and phosphorus levels. These were found to be present in satisfactory amounts.

Willett et al. (1948) reported ash values of 5.5 percent and 2.9 percent respectively for Hawaii's military and University cafeteria garbage. Calcium for the military waste was 0.4 percent. Salt (NaCl) content was not determined in this study but an earlier report by Ayres (1943) indicated that Hawaii's garbage had a more than adequate amount of salt (2.9 percent).

When Engel et al. (1957) sampled garbage in Virginia, ash content varied ($P < .01$) between the sources sampled. Calcium content also varied significantly ($P < .05$) but phosphorus did not. Of the sources sampled household garbage had the highest ash content (10.7 percent). Military garbage had the lowest (5.2 percent). Household waste also had the highest amount of calcium (1.7 percent) and military the lowest (0.4 percent). The workers concluded that the high paper content of household garbage and the use of lime for fly control were the factors responsible for these results. Ash content of the garbage also varied between the days of the week. Garbage collected on Friday had the lowest ash content (6.9 percent) while that collected on Thursday had the highest (11.4 percent). Seasonal effects included a high ash content during the summer (12.2 percent), a high calcium (1.3 percent), and phosphorus (0.4 percent) during the spring and a low phosphorus (0.2 percent) during the fall. In addition, the workers analyzed composite source samples for some of the minor elements (copper, cobalt, molybdenum, manganese and zinc). College dining room garbage and one hospital source appeared to be border line deficient in copper and cobalt. Zinc concentration was high (153 ppm to 925 ppm) in all sources sampled. The probable cause of this was attributed to the widespread use of galvanized containers for storing the material. Other than those previously mentioned all other trace elements were found to be in sufficient quantity to satisfy the requirements of growing swine.

Barth et al. (1966) extensively investigated the mineral content of garbage by source. He found, as in earlier studies, the ash content of municipal garbage to be the highest (9.8 percent). Institutional was the lowest of the major sources (6.2 percent). In addition to calcium and phosphorus, Barth et al. (1966) analyzed for copper, iron, magnesium and manganese. Values given for each source were an average of three seasonal composite values. There were no significant seasonal variations except for iron which was lower ($P < .05$) during the winter. All of the sources were found to be deficient in calcium for growing pigs except municipal material which was higher ($P < .05$) at 1.7 percent then hotel and restaurant, institutional or military wastes. The last three sources had a mean calcium content of 0.4 percent. All sources were slightly deficient in phosphorus. Copper, iron and magnesium were present in all sources in adequate amounts for growing swine. Manganese content was inadequate in all sources except one series of military samplings where it was found equal to the recommended requirement of 40 ppm. Data reported by Barth et al. (1966) agreed with the earlier work of Willett et al. (1948) and Engel et al. (1957) except that Engel showed calcium values to be twice that of Barth. Also copper and manganese values from all sources reported by Engel were only one-half of that shown in Barth's study.

Ether Extract Content

Ether extract is consistently higher in food waste products than common grain rations. A review of the literature indicates that the large amount of fat present in garbage may be undesirable in some cases due to accompanying low protein values.

Thomas and Hargrave (1931) determined the oil content of hotel, restaurant and first class cafe kitchen refuse to average 22.9 percent, 19.7 percent and 17.3 percent, respectively. These workers found week to week variation in oil level to be quite large varying from a high of 45.3 percent and a low of 8.5 percent from the same source. Boiling was carried out for sterilization and to partially degrease the material.

Woodman (1941 b) reported a fat content of 11.8 percent on a dry matter basis for processed urban swill collected during the winter. During the summer Britain's commercially dried, balanced swill product contained 11.0 percent fat. Woodman and Evans (1942) found military and processed urban swill to contain 28.5 percent and 11.8 percent ether extract respectively. Their study noted that even though military swill was quite high in fat, there would be little danger of producing soft oily carcasses because of the low iodine value of the swill fat.

When Engel *et al.* (1957) examined the fat content of garbage, they found no significant variation due to season or day of the week. Garbage sources sampled were military, household, hotel-restaurant and hospital (31.8 percent, 27.8 percent, 27.3 percent and 23.3 percent fat, respectively).

When Kornegay *et al.* (1965) examined garbage in New Jersey, they found no significant difference in fat content due to season or day of the week. However, some of the sources sampled were significantly different with military waste again having the highest fat content (a mean of 32.0 percent for 56 samples) and institutional waste the lowest with a mean of 14.7 percent for 58 samples. Coefficients of variation showed that ether extract was one of the most variable components in the analysis.

Early reports in Hawaii by Work *et al.* (1943) listed values of 31.4 percent and 32.5 percent fat for University and military garbage, respectively. Garbage used by Willett *et al.* (1946) in a feeding trial contained 24.4 percent fat. The long term study of military food wastes by Willett *et al.* (1948) showed ether extract content to average 29.8 percent for the four year period. University cafeteria material ranked higher at 33.4 percent.

Fatty acid composition is the factor largely responsible for the degree of firmness present in carcasses finished on different rations. Most of the research work relative to garbage was done before the development of the modern gas chromatographs which effectively measures the fatty acid composition of various fats. Some earlier workers (Woodman and Evans, 1942; Lovatt et al., 1943; and Hunter, 1919) did use iodine values to determine degree of firmness. The results obtained for garbage and grain fed hogs were variable.

Gross Energy Content

Kornegay et al. (1965) conducted the only study to date dealing with the gross energy content of garbage from various sources. They reported military material to have the highest gross energy content with a mean value of 5.67 Kcal./g. Institutional garbage had the lowest ($P < .01$) at 4.82 Kcal./g., while municipal and hotel-restaurant were higher at 5.10 and 5.33 Kcal./g., respectively. It was apparent that gross energy was directly proportional to the fat level present in each source. Of the 165 samples analyzed for the four sources, energy content proved to be the least variable component. No difference was noted due to day of the week, but garbage collected during the winter had a higher ($P < .05$) gross energy than that collected during the summer.

DIGESTIBILITY OF GARBAGE

Numerous studies to determine the apparent digestibility of common grains have been carried out with the pig, however, information about the digestibility of garbage is limited. In 1942 Woodman and Evans conducted a trial to determine the digestibility of three different types of swill in Great Britain. Three groups of two pigs each were used to test military swill, processed urban swill, and dried balanced swill. All six animals weighed between 180 and 200 pounds. After a period of adjustment to the swill being fed, each animal was placed in a digestion crate where collection of feces and urine took place for 14 days. Constipation difficulties were encountered once the animals were in cages. This was corrected by introducing middling into the swill. The digestibility of the swill was then calculated by difference.

A summary of the results obtained in this study are presented in Table I. A study of this table shows that all components of military swill are highly digestible when compared with the other two garbage sources. These findings served to confirm the belief that this type of food waste was of a concentrated nature. The authors also concluded that the high N.F.E. digestibility of processed urban swill was due to the fact that it was a winter collection thus containing more starchy potato peelings. The dried balanced swill was a summer collection which was high in pea pods and cabbage leaves.

Kornegay et al. (1965) also conducted a digestion trial using military, institutional and municipal garbage. Two weight classes of swine were used (averaging 81 and 128 pound) with four barrows in each group except municipal garbage where only two heavier pigs were utilized. A 10-day preliminary adjustment feeding period was followed by the total collection period of 6 days. In contrast to Woodman and Evans' (1942) study, Kornegay mixed the garbage and ground it in a 1/8" plate meat grinder before feeding. Water was fed ad libitum. In addition to the digestibility of the standard nutrients, the digestibility energy of each garbage along with a T.D.N. value was also determined in this trial.

TABLE I

CHEMICAL COMPOSITION AND APPARENT DIGESTION COEFFICIENTS OF SWILL (WOODMAN AND EVANS, 1942)

Item	Swill (D.M. Basis)		
	Military	Processed Urban	Dried and Balanced
Dry matter			
Composition%	-	-	-
Dig. coeff.%	92.6	80.5	61.1
Crude protein			
Composition%	20.4	14.7	34.2
Dig. coeff.%	90.3	61.0	75.5
Ether extract			
Composition%	28.5	11.8	12.0
Dig. coeff.%	95.5	77.0	81.3
Nitrogen free extract			
Composition%	43.6	57.9	26.5
Dig. coeff.%	98.7	95.8	64.5
Crude fiber			
Composition%	1.6	5.7	7.9
Dig. coeff.%	68.8	56.6	46.6

The results of this study are presented in Table II. All data are shown converted to a dry matter basis to facilitate comparisons with Woodman and Evans' (1942) study. Almost without exception the nutrients were more highly digested by the lighter pigs than by the heavier animals. This was especially noticeable when municipal garbage was fed. The digestible energy of this material for the lighter group of pigs is over 9 percent more than for the heavier group. A large portion of this difference can be attributed to the greater use of fat by light pigs.

Another interesting point in data reported by Kornegay et al. (1965) is the average dry matter intake. Heavier animals on institutional garbage consumed more than twice as much per day as any other group. Daily dry matter intake of the other groups was low in comparison to consumption of common grain rations for swine. This helps to reinforce the belief that young pigs cannot or will not consume sufficient quantities of high moisture garbage to meet their requirements for maximum growth.

In agreement with Woodman and Evans (1942), military material consistently had the highest digestibility of the three types tested. Municipal food waste had the poorest digestibility. This was partly due to the high fiber content.

In evaluating the high digestibility of fat, it is important to recall that digestion increases with the concurrent increase of some nutrients in the feed (Clawson et al., 1962). In addition, garbage fat is composed largely of neutral fat or triglycerides whereas the other

TABLE II

CHEMICAL COMPOSITION AND APPARENT DIGESTION COEFFICIENTS OF COOKED GARBAGE
(KORNEGAY *ET AL.*, 1965)

Item	Garbage (D.M. Basis)					
	Military		Institutional		Municipal	
	Light	Heavy	Light	Heavy	Light	Heavy
Number of barrows	4	4	4	4	4	2
Average daily wet garbage intake, lbs.	5.1	6.2	9.6	18.6	7.9	12.9
Average daily D.M. intake, lbs.	1.6	2.0	1.8	3.6	1.1	1.7
Dry matter						
Composition%	31.6	31.6	18.9	18.9	13.4	13.4
Dig. coeff.%	96.1^{a}	95.3^{a}	93.8^{a}	93.4^{a}	75.9^{b}	70.3^{c}
Crude protein						
Composition%	16.8	16.8	16.4	16.4	20.1	20.1
Dig. coeff.%	89.5^{a}	88.6^{a}	88.9^{a}	86.9^{a}	82.1^{b}	76.2^{c}
Ether extract						
Composition%	39.9	39.9	19.0	19.0	31.3	31.3
Dig. coeff.%	$96.2^{a,d}$	$95.8^{a,d}$	$91.4^{a,b,e}$	$91.4^{a,b,e}$	$89.4^{b,e}$	80.8^{c}
Crude fiber						
Composition%	2.5	2.5	2.6	2.6	9.7	9.7
Dig. coeff.%	$86.9^{a,e}$	$83.8^{a,e}$	$77.2^{a,d}$	$77.6^{a,d}$	39.6^{b}	20.7^{c}
N-free extract						
Composition%	33.9	33.9	55.6	55.6	29.9	29.9
Dig. coeff.%	98.7^{a}	97.6^{a}	98.3^{a}	98.3^{a}	77.1^{b}	72.0^{c}
Ash%	7.0	7.0	6.3	6.3	10.4	10.4
TDN%	136.7	135.8	110.1	109.0	106.0	95.5
Energy						
Gross, Kcal./g.	6.1	6.1	4.9	4.9	5.4	5.4
Dig. coeff.%	95.7^{a}	94.8^{a}	93.3^{a}	92.7^{a}	77.8^{b}	68.4^{c}

a,b,c means on the same line bearing same superscripts are not significantly different ($P < .01$).

d,e means on the same line bearing the same superscripts are not significantly different ($P < .05$).

extract of grain contains a large proportion of poorly digestible waxes and related materials.

EXPERIMENTAL PROCEDURE

COMPOSITION OF GARBAGE FOR SWINE IN HAWAII

Source of Data

Six commercial garbage feeding operations on the island of Oahu were selected for sampling. They were thought to be typical of the majority of garbage feeding units found in the State of Hawaii. Three of these operations were located in the Waianae area and three in the Koko Head-Waimanalo district. These farms used a mixture of garbage from various sources as do all garbage operations in Hawaii. Common sources from which garbage was collected by the producers included restaurants, school cafeterias, military bases, fish markets, bread and bakery companies, and wholesale produce markets. No municipal or household garbage was included in these collections.

The material was picked up in 50-gallon drums and transported to the feeding units by truck. The drums were emptied into a tank where the material was mixed and brought to a boil for a minimum of 30 minutes. Five of these producers used direct fire cookers and one utilized the steam injection system. Garbage was cooked on the day prior to feeding. No fat was removed from the cooker before sampling as is often done before feeding.

Method of Sampling

Samples of garbage were taken each day of the week (except Sunday) from each of the producers. The day of sample collection at the farms was rotated each week, i.e. first week--Monday, second week--Tuesday, etc. This allowed the farms to be sampled over a six week period with a total of six samples from each producer. A 3-gallon random sample was taken at the farm on each sampling day. Special stainless steel dippers with 5-foot handles were constructed to enable mixing and collection of homogenous samples.

At the Animal Science laboratory the entire 3-gallon sample was mixed, ground through a Kenmore waste disposer unit No. 6530 then remixed and ground a second time and remixed. Inedible materials such as paper, hard bones and large seeds were removed from the material. Such items constituted a very small portion of the garbage. After grinding and mixing thoroughly, a 32-ounce random sample was taken from each 3-gallon container. This smaller sample was capped, frozen and stored at -4°C. The remaining garbage was poured into 20-gallon containers, frozen, and saved for digestion study.

Proximate Analysis

After the sampling period was completed each 32-ounce sample was removed from the freezer and allowed to thaw. Each sample was then placed in a Waring Blender Model 700B and homogenized for four minutes. After blending, the sample was poured into a weighed aluminum foil pan, reweighed, and placed in a forced air drying oven at 70°C. for a period of 48 hours or until no further weight loss occurred. The dried material was then weighed and crushed and ground with a mortar and pestle until it had the consistency of fine meal. High fat content prevented grinding in an electric grinder. When electric grinding was tried a paste resulted, separation occurred, and the product was not suitable for convenient analysis. Duplicate samples of the dried material were then used for determinations of total nitrogen, ether extract, crude fiber, and ash (A.O.A.C., 1965).

Gross Energy

Duplicate samples of each dried garbage sample were weighed and used for gross energy determinations. Measurements were made using the Parr Adiabatic Calorimeter Series 1200 utilizing the No. 1101 double valve self-sealing oxygen bomb. Procedure and calculations were carried out according to Parr (1960).

Mineral Composition

Duplicate samples which had been ashed at 500°C. for 24 hours were made into test solutions by the following method: The ash was first wetted with a small amount of water. Ten mililiters of 1:3 HCL were then added and allowed to stand for four hours. The solution was filtered through S&S No. 589 white ribbon filter paper followed by several rinsings with distilled water. The filtrate and washing were brought to 100 ml with distilled water in a volumetric flask and throughly mixed. Dilutions of this solution were used to determine percent calcium and magnesium and parts per million of copper. Analyses for mineral composition was carried out using the Perkin-Elmer Model 290 automic absorption spectrophotometer. Standard curves and instrument conditions used were similar to those suggested in the Perkin-Elmer Analytical Methods Book (1966).

For percent phosphorus determinations a dilution of the ash solution was mixed with 10 ml of a HNO_3-vanadomolybdate reagent as described by Jackson (1958). Absorbance was read at 470 mu in a Beckman Model B spectrophotometer. The phosphorus level was calculated using a standard curve established from known concentrations.

Fatty Acid Composition of Fat

Garbage fat was obtained from an ether extract beaker which had been placed on the Goldfisch apparatus for approximately 20 hours. Methyl esters were prepared from these samples, following the method described by Hilditch (1956). Proportions of fatty acids present in each sample were analyzed by injecting the methyl ester into an aerograph Model A-600C gas chromatograph. The instrument contained a 5' x 1/8" stainless steel column that was packed with 20 percent DEGS, 5 percent isophthalic acid on 60/80 HMDS Chromosorb W. A Honeywell Electronik Recorder which utilizes a disc chart integrator was used to measure the various peaks of the fatty acids. Retention time on the column was the criteria used for identifying the fatty acids. From the total area of the acids capric (C10), dodecanoic (C12:1), myristic (C14), tetradecanoic (C14:1), pentadecylic (C15), palmitic (C16), palmitoleic (C16:1), heptadecylic (C17), stearic (C18), oleic (C18:1), linoleic (C18:2), and iso-oleic (C18iso) the percent by weight of each acid for each sample was calculated.

pH of Garbage

The pH of each fresh wet garbage sample was recorded using a Corning Model 7 pH meter.

DIGESTIBILITY OF GARBAGE FOR SWINE IN HAWAII

Digestion Study

Two digestion trials were conducted during the course of the study. Ten three-way cross (Hampshire x Yorkshire x Poland China) animals located at the Waialee Research Farm on Oahu were used for the first trial. Pigs averaging 112 pound liveweight were divided by sex into two equal lots and were provided water ad libitum. The ground garbage that had been stored in 20-gallon containers was thawed, weighed and poured into a specially constructed holding tank fitted at the bottom with an exit valve.

One hundred and sixty grams of dried technical grade chromium oxide (Cr_2O_3) were added to 315 Kg. of garbage. This amount was calculated to produce approximately 0.4 percent Cr_2O_3 on a dry matter basis. The contents of the holding tank were thoroughly mixed by hand for a one-hour period during which time a propane torch was used to heat the material. At the completion of mixing, the tank was covered with a canvas to keep it clean and to prevent insects from entering. A random sample was taken at various levels in the tank and used for chemical analysis.

Throughout the experiment the garbage in the tank appeared to stay wholesome and no fermentation was detected. As reported by Woodman (1941 b), a small amount of white mold did grow at the surface of the material but this did not seem to affect its quality.

The pigs were fed in iron troughts all the garbage that they would readily consume each day. Before each feeding numerous buckets of garbage were drained out of the tank and poured back in through the top to ensure adequate mixing. It was found that there was only enough garbage to sustain the animals for seven days. During the first few days consumption was poor because the pigs were unaccustomed to the feed. However on the fifth and sixth day they were consuming approximately 13 pounds per pig daily. On the morning of the seventh day fecal samples were collected and placed in a 70°C. drying oven for 72 hours. After grinding through a fine mesh they were used for proximate analysis.

The second digestibility trial was carried out in such a way as to allow a longer preliminary period of garbage feeding before fecal collections were made. Garbage was again collected from the same farms as previously described. The complete sample was saved for feeding after it had been ground. A total of 307 Kg. of garbage was used in this trial. Chromium oxide was also added in the same manner as previously described. Only 5 pigs (barrows) were used in this study to ensure an adequate amount of garbage. The animals averaged 106 pound and had the same breeding background as the first group.

Instead of leaving the mixed garbage in the holding tank for the entire feeding period, it was drained out into 3-gallon containers and stored in a cooler. Each morning the number of containers needed for that day were removed and gently heated before feeding. This was done with the expectation that palatability would be increased. A mixture of 50 percent grain and 50 percent garbage was fed for the first three days. This resulted in a more rapid adjustment to the garbage feed. After the third day only garbage was fed. On the afternoon of the eleventh day fecal samples were collected and dried in the same manner as the first trial.

Proximate Analysis of Feed and Feces

Duplicate samples of garbage and feces from the two digestibility trials were analyzed by proximate analysis according to A.O.A.C. (1965).

Quantitative Determination of Chromic Oxide

Ash samples of the feed and feces were analyzed for chromic oxide in a manner similar to that described by Carter et al. (1960). Each ash sample was transferred to a 100 ml. Kjeldahl flask using a polyethylene funnel. The crucible and funnel were then rinsed with a 5 percent solution of perchloric acid ($HClO_4$). Fifteen mililiters of a digestion reagent which contained 0.25 sodium molybdate aqueous solution mixed with an equal amount of concentrated $HClO_4$ was then added to the flask. Boiling chips were added and the mixture was heated until it turned bright orange (approximately 45 minutes). They were then swirled and reheated for 10 minutes to ensure complete digestion. A suction manifold was used to control toxic fumes. After cooling, the contents of each flask were rinsed and emptied into 500 ml. volumetric containers. They were then brought to volume with distilled water, shaken and left undisturbed for 12 hours to allow undissolved material to settle. A 15 ml. portion was then pipetted and transferred to a cuvette. Transmission readings were taken at 440 mu in a Beckman Model B spectrophotometer. Chromic oxide level of feed and feces were determined from a standard curve that was established by processing known concentrations of Cr_2O_3 in the same manner. Percent digestibility was calculated using the formulas worked out by Reid (1950) and Kane et al. (1950) and described by Carter et al. (1960). The formula for digestibility used in this trial was:

$$\%\text{Dig.} = 100 - 100 \left(\frac{\%Cr_2O_3 \text{ in feed}}{\%Cr_2O_3 \text{ in feces}} \times \frac{\%\text{nutrient in feces}}{\%\text{nutrient in feed}} \right)$$

STATISTICAL METHODS

An analysis of variance was carried out on the data using the methods described by Snedecor and Cochran (1968). After the analysis of variance, Duncan's Multiple Range Test (1955) was used to locate significant differences between producers and day of the week sampled.

EXPERIMENTAL RESULTS AND DISCUSSION

COMPOSITION OF GARBAGE FOR SWINE IN HAWAII

The chemical composition of the dry matter of cooked garbage from six producer sources is summarized in Tables III and IV. The mean and standard deviation of each nutrient is given by producer source. Considerable variation in garbage composition due to source is shown.

The mean moisture content for all garbage sampled was 86.8 percent. This high moisture content is probably the result of the addition of large amounts of water prior to cooking. The 13.2 percent dry matter content is comparable to that of the institutional garbage (13.7 percent D.M.) reported by Kornegay et al. (1965) or the household material (14.7 percent D.M.) reported by Engel et al. (1957). Willett et al. in 1948 reported a much higher (30.1 percent average) dry matter content in Hawaii's garbage. It seems logical to conclude that the difference in dry matter of garbage today and that sampled by Willett et al. (1948) is due to the water added by the producer for cooking. According to the values developed by Kornegay in 1965, pigs weighing 100 pound would not be able to consume enough of the garbage sampled in this study to meet their nutritive requirements.

Protein (19.7 percent) in the dry matter of the garbage in this study was higher than values reported by Engel et al. (1957) or Kornegay et al. (1965) but was comparable to the military garbage (20.4 percent) reported by Woodman and Evans (1942). Protein values (21.9 percent) reported by Willett et al. (1948) exceeded those found in this study.

TABLE III

COMPOSITION OF COOKED GARBAGE IN HAWAII BY PRODUCER

Producer	Dry Matter		Percent of dry matter								Gross Energy		Sample
			Crude Protein		Ether Extract		Crude Fiber		N.F.E.		Kcal./gm.D.M.		
	Mean %	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Size
A	$11.1^{a,b}$	0.6	$18.0^{a,b}$	3.5	$30.3^{a,b}$	7.4	4.3^{a}	1.2	44.5^{c}	6.3	5.59^{a}	0.38	6
B	16.8^{c}	4.1	$18.6^{a,b}$	2.8	22.2^{a}	5.1	7.4^{b}	2.8	45.4^{c}	4.1	4.72^{b}	0.27	6
C	16.1^{c}	2.8	20.5^{b}	3.7	34.1^{b}	7.4	4.5^{a}	1.7	34.4^{b}	7.8	5.57^{a}	0.57	6
D	$13.8^{b,c}$	3.3	$18.8^{a,b}$	2.1	$28.8^{a,b}$	10.1	4.8^{a}	0.5	41.0^{c}	8.5	5.46^{a}	0.55	6
E	8.7^{a}	1.9	27.3^{c}	4.3	34.4^{b}	5.4	$5.6^{a,b}$	1.6	24.2^{a}	3.4	5.47^{a}	0.45	6
F	12.6^{b}	4.1	15.1^{a}	3.4	54.5^{c}	9.1	5.1^{a}	0.9	20.1^{a}	6.2	6.38^{b}	0.31	6
Average	13.2	2.6	19.7	3.6	34.1	7.5	5.3	1.5	35.0	6.3	5.53	0.37	36

a,b,c - means in the same column bearing the same superscripts are not significantly different at $P < .05$.

TABLE IV

COMPOSITION OF COOKED GARBAGE IN HAWAII BY PRODUCER

Producer	Percent of Dry Matter								PPM of D.M.		Wet Basis		Sample Size
	Ash		Calcium		Phosphorus		Magnesium		Copper		pH		
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	
A	5.9^{a}	1.3	0.64	0.30	0.43^{a}	0.15	0.07^{a}	0.02	2.6	2.2	$4.7^{b,c}$	0.4	6
B	6.4^{a}	1.5	0.65	0.41	0.42^{a}	0.19	0.12^{b}	0.03	2.9	0.5	$4.6^{a,b}$	0.1	6
C	6.2^{a}	0.8	0.66	0.19	0.49^{a}	0.08	0.10^{a}	0.02	2.1	2.4	4.9^{c}	0.1	6
D	6.6^{a}	0.8	0.71	0.13	0.44^{a}	0.04	0.09^{a}	0.01	2.7	1.1	4.4^{a}	0.2	6
E	8.5^{b}	1.5	1.16	0.56	0.76^{b}	0.27	0.20^{c}	0.02	2.7	0.6	4.9^{c}	0.4	6
F	5.2^{a}	1.2	0.60	0.12	0.35^{a}	0.08	0.09^{a}	0.03	1.4	0.9	$4.8^{b,c}$	0.2	6
Average	6.5	1.3	0.73	0.35	0.49	0.17	0.11	0.02	2.4	1.9	4.7	0.2	36

a, b, c - means in the same column bearing the same superscripts are not significantly different at $P < .05$.

The high ether extract contents of the garbage (Table III) were comparable to those reported by Woodman and Evans (1942), Engel __et al.__ (1957), Kornegay __et al.__ (1965) and Willett __et al.__ (1948). Although these studies represent a spread of 27 years, it appears that fat level in garbage has remained relatively constant. The source of the high level of ether extract in the garbage from farm F (54.5 percent) could not be determined.

Crude fiber level from the garbage evaluated in this study was near the high level reported by Engel __et al.__ (1957) in household material (6.8 percent) and Kornegay __et al.__ (1965) in municipal garbage (8.4 percent). The fiber content of military garbage has generally been reported to be lower than that found in this study. Willett __et al.__ (1948) reported 2.0 percent, Kornegay __et al.__ (1965)--2.9 percent and Woodman and Evans (1942)--1.6 percent fiber in military garbage. The fiber content of the garbage in this study appears high enough to reduce efficiency in feed utilization by the pig.

The N.F.E. content (Table III) of the garbage from three producers (C, E and F) were below levels reported in the literature. The level of N.F.E. in the garbage from farms A, B and D were near the levels given by Kornegay __et al.__ (1965) for municipal (44.0 percent) and military (43.8 percent) garbage.

Gross energy values for the dry matter of garbage were similar to those reported by Kornegay __et al.__ (1965). The high level of 5.53 $\pm$ 0.63 Kcal./g. of dry matter found in garbage is higher than normally found in standard grain rations and reflects the high fat content of this material.

Ash content of the garbage in this study (Table IV) was similar to the values reported in earlier studies by Kornegay et al. (1965), Woodman and Evans (1942), Willett et al. (1948) and Engel et al. (1957). When composition of ash was examined, a sufficient amount of calcium (D.M. basis) was found to meet the N.R.C. (1968) requirement for growing swine, although the level was quite variable between different samples. Based on the average composition, phosphorus was also adequate to meet the N.R.C. (1968) requirement of 0.4 percent. The magnesium level of 0.11 percent found in the garbage of this study exceeded the highest level reported by Barth et al. (1966) and in each sample analyzed it exceeded the minimum requirement as stated by the N.R.C. (1968) of 0.04 percent.

The copper content of 2.4 ppm found in this study was less than 50 percent of the N.R.C. (1968) recommended level of 6 ppm for swine. One would expect a fast growing pig fed on this garbage, without another copper source, to show symptoms of copper deficiency.

The pH values of wet garbage in Table IV are almost identical to those found in a series of military samplings by Engel et al. (1957).

VARIATION DUE TO PRODUCER

After composition data by producer were subjected to an analysis of variance, the significant components (Table V) were analyzed by Duncan's Multiple Range Test (1955). Results are shown in Tables III and IV.

Dry Matter Content

The dry matter of the garbage from farms B (16.8 percent) and C (16.1 percent) was higher ($P < .05$) than that from farms A, E and F.

TABLE V

ANALYSIS OF VARIANCE ON COMPOSITION DATA
OF COOKED GARBAGE IN HAWAII

Source of Variation	d.f.	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	NFE	Gross Energy
Day of Week	5						*
Producer	5	**	**	**	*	**	**
Error	25	6.8	12.7	56.5	2.4	39.8	0.14

Source of Variation	d.f.	Ash	Calcium	Phosphorus	Magnesium	Copper	pH
Day of Week	5						**
Producer	5	**		**	**		**
Error	25	1.6	0.12	0.03	0.0005	3.6	0.04

* significant at 5 percent level.

** significant at 1 percent level.

Producer B, whose garbage had the highest content of dry matter, used the steam injection cooking apparatus. However, producer C used a direct fire cooker and also had a garbage of high dry matter content with less variation (S.D. 2.8); therefore, it cannot be concluded that the steam injection method of cooking was responsible for the higher dry matter in producer B's garbage. These data do indicate that low dry matter in garbage is its greatest limiting factor for swine feed. These data also indicate that more water is often added to garbage than is necessary for cooking, thereby diluting the nutrients.

Crude Protein Content

Protein content of garbage from farm E (27.3 percent) was higher ($P < .05$) than that of the other 5 farms. It was noted that large amounts of wastes from a fish market were present in garbage from this farm. The protein content of garbage from producer A, B, C and D was similar. Garbage from producer F had the lowest protein content (15.1 percent) but only significantly lower ($P < .05$) than garbage from producer C and E. The mean level of protein in garbage from some farms appeared to be adequate for growing swine. However, due to high energy levels of the dry matter and the within source variations, the pigs on some farms would probably benefit from protein supplementation.

Ether Extract Content

The ether extract content (54.5 percent) of the garbage sampled from farm F was higher ($P < .05$) than that from other farms. Garbage from farm B had the lowest fat content (22.2 percent) but only significantly lower than that from farms C, E and F. Due to the low dry matter content, hence low dry matter intake of all the garbage sampled, the practice of skimming off fat before feeding seems questionable. This removed fat could best serve as a valuable energy source to growing pigs even if supplementation of protein or other dry feed is needed in order to utilize this high fat.

Crude Fiber Content

Garbage from farm B had a significantly higher ($P < .05$) crude fiber content (7.4 percent) than the garbage from any other farm except farm E (5.6 percent). Material from farms A, C, D, E and F were similar in crude fiber and did not vary significantly from one another. Garbage from farm A had the lowest fiber content with 4.3 percent (but only significantly lower than that from farm B). In checking sources it was found that this farm received a higher proportion of garbage from the military than some of the other farms. Kornegay et al. (1965) and Engel et al. (1957) reported a lower crude fiber content in military garbage than other sources sampled.

N.F.E. Content

Garbage from farm F had the lowest N.F.E. content (20.1 percent). This was significantly lower ($P < .05$) than four other producers (A, B, C and D). An inverse relationship existed between N.F.E. and ether extract for producers B, C, E and F. A low N.F.E. content corresponded to a concurrently high ether extract value. Material from farm B had the highest N.F.E. value of 45.4 percent and the lowest fat value (22.2 percent).

Gross Energy Content

Gross energy content of garbage varied significantly between farms sampled (Table III). A value of 6.38 Kcal./g. was found in the dry matter of garbage from farm F. This was the highest of the six sources sampled and was significantly higher ($P < .05$) than that from farms A, C, D or E. A correspondingly high ether extract value was responsible for this high gross energy. Garbage from farm B had a significantly lower ($P < .05$) gross energy content (4.72 Kcal./g.) than that from farms A, C, D or E. The low standard deviations as listed in Table III for gross energy values indicate that this constituent was quite consistent within source. This is in agreement with work by Kornegay et al. (1965) who reported gross energy as the least variable component in garbage.

Ash Content

Garbage sampled from farm E had a significantly higher ($P < .05$) ash content (8.5 percent) than material from the other five producers, (Table IV). This may have been caused by the numerous small bones present from the fish waste incorporated into this farm's garbage. The ash content of material from farms A, B, C, D and F (5.9, 6.4, 6.2, 6.6 and 5.2 percent, respectively) were not significantly different.

Calcium, Phosphorus, Magnesium and Copper Content

Mean values for calcium did not vary significantly between farms or day of the week. Garbage from farm E had the highest calcium content (1.16 percent) and this may also have been a reflection of the fish bones present. Garbage from farm A had the lowest calcium content (0.64 percent). Although the range between the lowest and highest mean values were large, within variation prevented these differences between farms from being statistically significant.

Garbage from producer E also had a higher ($P < .05$) phosphorus content (0.76 percent) than material from the other five producers. No significance existed between differences in phosphorus content of garbage from farms A, B, C, D and F.

Magnesium content of garbage from producers A, C, D and E were not significantly different from one another. Garbage from farm B had the lowest ($P < .05$) magnesium content (0.12 percent) and farm E the highest (0.20 percent).

Differences in copper content of the garbage sampled were low, quite variable and not significantly different. The means ranged from 1.4 ppm to 2.9 ppm on a dry matter basis. The reason for the low copper content found in garbage sampled in Hawaii is unknown. Engel et al. (1957) reported that hospital garbage had the lowest copper content of any garbage in their study and this was three times the level found in the present study. Barth et al. (1966) reported that military garbage contained the lowest copper content in their study but this was nine times the level found in the garbage sampled in this study.

pH of Garbage

The pH of garbage varied significantly between the farms sampled. Material from farm C and E had the highest pH (4.9) but these were only significantly higher ($P < .05$) than that material from farm B and D (4.6 and 4.4, respectively). The pH of garbage was an indication of the acidity of the components present in the material or the degree of fermentation that had taken place.

VARIATION DUE TO DAY OF THE WEEK

Dry matter composition of garbage by day of the week sampled is presented in Tables VI and VII. When these data were subjected to an analysis of variance only differences in gross energy and pH, among the 12 constituents examined, were found to be statistically significant (Table V). Although considerable variation existed between the means, large within source variations prevented significance. This low relationship between composition and day of the week sampled is in agreement with results reported by Kornegay _et. al._ (1965) and Engel _et al._ (1957).

Duncan's Multiple Range Test (1955) revealed that garbage collected on Monday (Table VI) contained the highest gross energy on a dry matter basis. This level of 5.94 Kcal./g. was significantly higher ($P < .05$) than that of garbage collected Tuesday, Thursday and Friday (5.27, 5.40 and 5.31 Kcal./g., respectively). The high fat content (39.2 percent) of garbage collected on Monday was probably responsible for the high gross energy of this garbage.

Garbage sampled on Thursday had the highest pH but these values were significant only when compared to the garbage sampled Monday, Tuesday and Saturday. The cause for the variation in pH due to day of the week could not be explained.

The mean dry matter of the garbage collected on Saturday was 16.5 percent while that collected on other days varied from 11.8 percent to 13.2 percent. These differences, however, were not significant nor was the higher mean ether extract of the garbage collected on Monday. In

TABLE VI

COMPOSITION OF COOKED GARBAGE IN HAWAII
BY DAY OF THE WEEK SAMPLED (D.M. BASIS)

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sample Size
Dry Matter %	12.6	12.8	11.8	12.2	13.2	16.5	6
Crude Protein %	19.6	17.4	19.5	20.0	21.3	20.5	6
Ether Extract %	39.2	33.5	34.9	33.3	29.4	34.1	6
Crude Fiber %	5.0	5.5	5.7	5.0	5.7	4.6	6
N.F.E. %	30.2	37.6	35.8	34.3	36.5	35.2	6
Gross Energy Kcal./gm.	5.94^{b}	5.27^{a}	$5.72^{a,b}$	5.40^{a}	5.31^{a}	$5.56^{a,b}$	6

a,b,c - means on the same line bearing the same superscripts are not significantly different at $P < .05$.

TABLE VII

COMPOSITION OF COOKED GARBAGE IN HAWAII
BY DAY OF THE WEEK SAMPLED (D.M. BASIS)

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sample Size
Ash %	6.1	6.0	6.9	7.4	7.1	5.6	6
Calcium %	0.67	0.53	0.72	0.94	0.93	0.62	6
Phosphorus %	0.43	0.38	0.48	0.59	0.57	0.45	6
Magnesium %	0.11	0.11	0.12	0.12	0.12	0.09	6
Copper, ppm	3.1	1.9	2.6	1.3	3.3	2.3	6
pH	4.5^{a}	4.5^{a}	$4.9^{b,c}$	5.0^{c}	$4.7^{a,b,c}$	$4.6^{a,b}$	6

a,b,c - means on the same line bearing the same superscripts are not significantly different at $P < .05$.

contrast, the means for crude protein and crude fiber were relatively constant for each day of the week sampled.

FATTY ACID COMPOSITION OF FAT

In recent years concern has been expressed over the amount of saturated fatty acids present in human diets. There is presently much effort in human nutrition to replace saturated with unsaturated fats. The reason for this is the alleged relationship between saturated fat intake and arteriosclerosis. It has generally been felt that garbage-fed swine produce carcasses that are high in unsaturated fatty acids. However, early workers determining iodine values reported conflicting and variable results. The use of the term "soft" pork when referring to garbage-fed swine is widespread.

The fatty acid composition of the fat present in garbage sampled in Hawaii was investigated to determine the degree of unsaturation of this material. As far as is known no work has been carried out on the composition of garbage fat using a gas chromatograph, thus no comparisons can be made.

A summary of the mean for each producer, followed by the standard deviation, of six major and six minor fatty acids in garbage fat is shown in Tables VIII and IX. The proportions of myristic (C14), palmitic (C16) and stearic (C18) acid (2.9, 23.3 and 10.0 percent, respectively) in the garbage fat were higher than those found in rations using corn or soybean oil. Also larger amounts of the unsaturated acids palmitoleic (C16:1) and oleic (C18:1) were present in the garbage fat

TABLE VIII

PROPORTION OF MAJOR FATTY ACIDS OF GARBAGE FAT
(PERCENT BY WEIGHT)

Producer	C14		C16		C16:1		C18		C18:1		C18:2		Sample
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Size
A	2.3^{a}	0.1	24.8	2.2	5.5^{c}	2.5	8.9^{a}	0.9	$39.1^{a,b}$	1.8	$16.1^{a,b,c}$	1.9	6
B	3.2^{b}	0.5	23.2	1.5	$4.0^{a,b}$	0.6	$9.6^{a,b}$	1.0	36.7^{a}	3.6	19.4^{c}	5.2	6
C	3.1^{b}	0.5	22.9	0.8	$4.5^{a,b,c}$	0.6	11.9^{c}	0.9	$39.7^{a,b}$	2.1	$14.5^{a,b}$	3.2	6
D	$2.9^{a,b}$	0.5	22.6	1.8	3.6^{a}	0.5	$9.8^{a,b}$	0.8	40.5^{b}	2.3	$17.7^{b,c}$	2.4	6
E	3.4^{b}	0.7	22.5	0.7	$5.3^{b,c}$	0.6	$9.4^{a,b}$	1.8	$39.2^{a,b}$	2.3	$14.2^{a,b}$	1.3	6
F	$2.8^{a,b}$	0.4	23.8	1.2	$4.2^{a,b,c}$	0.4	10.7^{b}	0.9	42.1^{b}	1.7	12.1^{a}	2.7	6
Average	2.9	0.5	23.3	1.6	4.5	1.1	10.0	1.2	39.6	2.5	15.7	3.4	36

a,b,c - means in the same column bearing the same superscripts are not significantly different at $P < .05$.

TABLE IX

PROPORTION OF MINOR FATTY ACIDS OF GARBAGE FAT
(PERCENT BY WEIGHT)

Producer	C10		C12:1		C14:1		C15		C17		C18iso		Sample
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Size
A	0.3^{a}	0.1	$0.5^{a,b}$	0.2	0.4^{a}	0.1	0.3^{a}	0.1	0.5^{a}	0.3	0.3^{a}	0.1	6
B	0.8^{b}	0.4	1.1^{c}	0.4	$0.6^{a,b}$	0.2	$0.4^{a,b}$	0.1	0.7^{a}	0.3	0.3^{a}	0.1	6
C	$0.6^{a,b}$	0.2	$0.9^{b,c}$	0.3	0.8^{b}	0.3	$0.6^{b,c}$	0.2	$1.2^{b,c}$	0.4	$0.7^{a,b}$	0.3	6
D	0.9^{b}	0.3	$0.9^{b,c}$	0.2	0.5^{a}	0.1	$0.5^{a,b,c}$	0.2	0.7^{a}	0.3	0.3^{a}	0.2	6
E	0.8^{b}	0.3	1.2^{c}	0.6	0.8^{b}	0.3	0.8^{c}	0.3	1.5^{c}	0.4	1.0^{b}	0.4	6
F	0.3^{a}	0.1	0.3^{a}	0.1	0.5^{a}	0.2	$0.4^{a,b}$	0.1	$0.8^{a,b}$	0.3	0.6^{a}	0.2	6
Average	0.6	0.3	0.8	0.4	0.6	0.2	0.5	0.2	0.9	0.3	0.5	0.3	36

a,b,c - means in the same column bearing the same superscripts are not significantly different at $P < .05$.

(4.5 percent and 39.6 percent). The mean value of 15.7 percent ± 3.9 for linoleic acid (C18:2) was, however, considerably lower than the content found in the lipids of soybean oil meal or corn. Brooks in 1967 showed that the level of linoleic acid (C18:2) in pork tissue varied more directly with its total level of intake rather than with its ratio in the fat of the feed. Because of the exceptionally high fat content of garbage when compared to grain rations for swine (34.1 percent vs. 2 percent-10percent), the total amount of linoleic acid (C18:2) received by a pig eating garbage would far exceed that obtained from a corn/soybean oil meal ration. In a grain ration containing 3.3 percent fat the linoleic (C18:2) content was found to be 55.2 percent (Brooks, 1967). Total linoleic acid (C18:2) content of this ration would be 1.8 percent. In contrast, garbage sampled in Hawaii had a mean fat content of 34.1 percent with 15.7 percent as linoleic acid (C18:2). Total amount received by a pig eating this garbage would be 5.4 percent or three times as much linoleic acid (C18:2) as when on the grain ration.

Statistical Analysis of Fatty Acid Data

Table X shows the analysis of variance for fatty acid data as examined by farm source and by day of the week. The variation between farm was found to be significant for each fatty acid except palmitic acid (C16). On the other hand, no significant variation was found due to day of the week collected.

Results from Duncan's Multiple Range Test (1955) which are listed in Tables VIII and IX showed that a higher ($P < .05$) stearic acid (C18)

TABLE X

ANALYSIS OF VARIANCE OF DATA ON SIX MAJOR AND SIX MINOR FATTY ACIDS OF GARBAGE FAT

Source of Variation	d.f.	C14	C16	C16:1	C18	C18:1	C18:2
Day of the Week	5						
Producer	5	*		**	**	*	*
Error	25	0.3	2.6	1.2	1.6	6.1	11.5

Source of Variation	d.f.	C10	C12:1	C14:1	C15	C17	C18iso
Day of the Week	5						
Producer	5	**	**	*	**	**	**
Error	25	0.1	0.2	0.1	0.1	0.1	0.1

* significant at 5 percent level.

** significant at 1 percent level.

content (11.9 percent) was present in the garbage fat from farm C than from the fat of any other source. The fat in the garbage from farm B had a higher ($P < .05$) linoleic acid (C18:2) content (19.4 percent) than that of the five other farms. This garbage also had the lowest level of fat (22.2 percent).

DIGESTIBILITY OF COMPOSITE GARBAGE IN HAWAII

The chemical composition and digestibility coefficients of the garbage used in both trials 1 and 2 are presented in Table XI. The composite sample of garbage from the six farms had a composition similar to the values reported for all six producers.

Digestion coefficients for each nutrient in trial 2 were higher than in trial 1. This was reflected in the digestion coefficients for dry matter (78.6 and 87.3). Coefficients of variation were also lower in trial 2 than in trial 1. This is believed to be due to the longer preliminary adjustment period used in trial 2. Values shown for trial 2 are therefore believed to be a more accurate estimation of the digestibility of this material.

Apparent digestion coefficients determined in trial 2 for dry matter and crude protein fell between those values reported by Woodman and Evans (1942) for military and processed urban swill (Table I), and between values reported by Kornegay et al. (1965) for municipal and institutional material (Table II). This seems logical since the garbage in this study was collected from many different sources.

TABLE XI

APPARENT DIGESTION COEFFICIENTS AND CHEMICAL COMPOSITION OF COMPOSITE COOKED GARBAGE IN HAWAII (DRY MATTER BASIS)

Item	Trial I	Trial II
No. of barrows	5	5
Av. wt. of barrows	106.8	105.5
No. of gilts	4	-
Av. wt. of gilts	118.0	-
Dry Matter		
Composition, %	13.7	11.4
Dig. Coeff., %	78.6	87.3
Coeff. of Variation	2.0	-
Crude Protein		
Composition, %	22.0	16.3
Dig. Coeff., %	81.0	83.1
Coeff. of Variation	1.9	1.0
Ether Extract		
Composition, %	41.9	35.9
Dig. Coeff., %	93.0	94.1
Coeff. of Variation	2.4	1.7
Crude Fiber		
Composition, %	5.1	3.1
Dig. Coeff., %	67.1	72.5
Coeff. of Variation	5.6	4.0
N-Free Extract		
Composition, %	23.0	38.1
Dig. Coeff., %	71.2	88.6
Coeff. of Variation	4.9	1.47
Ash %	8.0	6.6
TDN %	125.2	125.6
Energy		
Gross, Kcal./g.	5.86	6.49
Dig. Coeff., %	82.3	87.8
Dig. Energy, Kcal./g.	4.82	5.70
Coeff. of Variation	3.2	1.1

The high digestibility of fat found in this study (93.0 and 94.1) was similar to that reported for military garbage by Kornegay *et al*. (1965) and Woodman and Evans (1942) (95.8 and 95.5, respectively). Digestion coefficients of this magnitude for fat would be expected only in high fat diets. Clawson *et al*. (1962), Greeley *et al*. (1964), and Lowrey *et al*. (1962) showed that an increase in the digestibility of fat occurred when the level in the ration was increased.

The average values for the digestibility of crude fiber resembled those reported by Kornegay *et al*. (1965) for institutional garbage, and Woodman and Evans (1942) for urban swill (Tables I and II).

Digestion coefficients found in this study for N.F.E. were lower than coefficients found in both the military and institutional materials reported by Kornegay *et al*. (1965) and higher than those reported for municipal garbage. Woodman and Evans (1942) also reported high N.F.E. digestibility in military and urban swill (98.7 and 95.8, respectively). These values probably reflected the higher N.F.E. content in the feed (43.6 percent and 57.9 percent, respectively) and also the nature of this material.

The digestion coefficients for gross energy reported in this study were between the low found in municipal and the medium found in institutional garbages reported by Kornegay *et al*.(1965). However, the digestible energy values shown in this study for garbage were still 25-30 percent higher than that reported for grain/meal rations by Kornegay in 1965.

SUMMARY AND CONCLUSIONS

The chemical composition of cooked garbage was determined from samples taken from six hog farms feeding garbage on the island of Oahu. Sampling was done so that variation due to day of the week and farm could be checked over a six week period. Three gallon random samples were taken from each farm for each day of the week over the six-week period. Day of the week sampled at each farm was rotated each week, i.e. first week--Monday, second week--Tuesday, etc. No Sunday collections were made. Each sample was processed by passing it through a disposal unit. A 32-ounce sample was then removed, homogenized in a blender, dried in a forced air oven to a constant weight, pulverized and used for chemical analyses. Samples were analyzed for crude protein, ether extract, crude fiber, N.F.E., pH, ash, gross energy, calcium, phosphorus, magnesium and copper. Proportions of 12 fatty acids in garbage fat were determined by gas chromatography.

Apparent coefficients of digestion for crude protein, ether extract, crude fiber, N.F.E. and gross energy were determined using the chromic oxide indicator technique. Three way cross-bred pigs (Hampshire x Yorkshire x Poland China) averaging approximately 109 pound were used for the digestion trials.

Analysis of variance was conducted on composition data to determine if statistically significant differences existed between producers or day of the week sampled. After the analysis of variance, Duncan's Multiple Range Test (1955) was used to locate existing significant differences.

Dry matter content of garbage sampled was extremely low and highly variable. Differences between farms ranged from 8.7 percent to 16.8 percent. This great variation indicates an area for considerable improvement in preparation before feeding.

The protein level of garbage sampled showed significant differences due to farm source. Protein content means ranged from 15.1 percent to 27.3 percent. Protein levels on some farms appeared to be adequate for growing swine while others appeared to need supplementation due to the high energy level in the dry matter of the garbage and because of large within farm variation.

The level of fat in the dry matter of garbage was high (22.2 percent to 54.5 percent) when compared to grain rations. Significant variation existed between farms. High digestion coefficients (93.0 and 94.1) were found for this material.

Crude fiber content of garbage sampled (4.3 percent to 7.4 percent range) was generally higher than that reported in other studies on garbage. Significant variation existed between the six producers.

N.F.E. contents were generally lower than those reported in other studies on garbage. Significant variation between producers existed with a mean range of 20.1 percent to 45.4 percent. Digestion coefficients from other studies on garbage were generally higher for N.F.E. than those found in this study.

Means for gross energy content were large and significantly different between producer and day of the week. Garbage collected on Monday had the highest gross energy content but only significantly higher than that collected on Tuesday, Thursday and Friday. Means for farm sampled ranged from 4.72 Kcal./g. to 6.38 Kcal./g. and the means for day of the week sampled were from 5.27 Kcal./g. to 5.94 Kcal./g. Gross energy and digestible energy were higher in garbage than grain rations for swine when compared on a dry matter basis.

Garbage from one farm had a significantly higher ($P < .05$) ash content (8.5 percent). No significant variation existed between the other five producers. The mean range for ash content was from 5.2 percent to 8.5 percent.

Calcium content was not significantly different between farms sampled. Mean calcium contents of garbage from all farms were adequate for growing swine but large within source variation was shown.

Phosphorus content of garbage sampled was significantly different ($P < .05$) between producers. Mean phosphorus values exceeded the N.R.C. (1968) requirement of 0.4 percent, except for the garbage sampled from one of the farms. The mean for all producers ranged from 0.35 percent to 0.76 percent.

Magnesium content of the garbage from all farms was high and variable. Means for all farms (0.09 percent to 0.20 percent) were significantly different ($P < .05$). Means for magnesium content of this garbage exceeded all values reported for garbage in the literature.

Copper content was low and did not vary significantly between farms sampled. The mean range was from 1.4 ppm to 2.9 ppm. None of the samples met the N.R.C. (1968) requirement of 6 ppm for growing swine. Fast growing pigs fed this garbage alone would probably show deficiency symptoms if supplementation was not made.

3. Copper is deficient in Hawaii's garbage and supplementation for this mineral should be made.
4. Fiber content of this garbage is reaching the permissible limit for growing swine. Efforts should be made to remove paper and other fibrous materials from this garbage before cooking.
5. Ether extract content of garbage is high but the removal of fat prior to feeding does not appear justified.
6. Pigs fed garbage will develop "soft" carcasses which are high in unsaturated fat. This is due to the high fat content of garbage which causes a large linoleic acid (C18:2) intake. This is not undesirable in view of the present trend toward less saturated fats in human diets.

The pH value determined for each wet garbage was significantly different between farms and day of the week sampled. The mean range from producers was from 4.4 to 4.9 and the mean range for day of the week was from 4.5 to 5.0.

Of the 12 fatty acids examined from the garbage fat, the proportions of seven were significantly different at the 1 percent level due to farm source (C10, C12:1, C15, C16:1, C17, C18 and C18iso) and four significant at the 5 percent level (C14, C14:1, C18:1, and C18:2). Palmitic (C16) variation was not significant. None of the fatty acids were significantly different between day of the week sampled. The proportions of C14, C16, C16:1, C18 and C18:1 found in garbage fat were higher than those found in fat from common grain rations for swine. Linoleic acid (C18:2) content was lower in the garbage fat (15.7 percent average). However, total C18:2 intake by swine eating garbage alone would be much higher than for swine eating grain rations because of the high fat content of the former. Total level of linoleic acid (C18:2) intake may be the most important factor determining the production of unsaturated or "soft" pork.

Under the conditions of this experiment, the following conclusions appear justified:

1. Dry matter content of garbage in Hawaii would be increased by curtailing the amount of water added prior to cooking and the addition of more water before feeding cannot be justified.
2. For young swine, protein supplementation of garbage is necessary in order to assure protein adequacy at all times.

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