COFFEE GROUNDS AS A GRAIN REPLACEMENT IN RATIONS FOR GROWING-FINISHING PIGS

by

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TABLE OF CONTENTS

LIST OF TABLES

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Chapter I

INTRODUCTION

In recent years, the search for alternate, cheaper sources of nutrients for use in swine rations to substitute for one or more of the three basic feed ingredients (corn, sorghum and soybean meal) has been a major problem facing swine producers in Nigeria. The present competition between human beings and swine for available grains has resulted in a considerable rise in the prices of these ingredients and has also initiated a keen interest in the search for cheaper sources of ingredients, preferably by products, which are inedible to man. Nigeria seems to be producing about enough grains for human consumption, no excess has been reported, and the farmers therefore cannot afford to feed too much of their grains to swine.

Production of robusta coffee is increasing in Nigeria, especially in the Riverain areas of Kwara state. In 1972/73, production of coffee in Nigeria rose to five million one hundred thousand kg. (5,100,000 kg) with four million two hundred thousand kg. (4,200,000 kg) exportable. Local annual consumption therefore amounts to 900,000 kg (USDA Stat. Report, March 1973). Potential areas for coffee production are estimated at over 10,000 acres (F.A.O., 1966). With a steady rise in coffee production, Nigeria has become a potential site for establishment of a coffee industry. In response to this potentiality, Nescafe now has a factory producing instant coffee in Nigeria.

Wherever instant coffee is manufactured, large quantities of coffee

grounds, resulting from the preparation of soluble coffee are available. This waste constitutes a disposal problem which could be solved economically if use could be found for it in the feed industry. So far, coffee grounds have not been used as an ingredient in swine feeds in Nigeria.

This study was designed to determine if coffee grounds could become a potential, relatively inexpensive feed ingredient in the ration for swine. The inedible "waste" would then be converted into animal protein for human consumption. The study was planned to determine the acceptability and/or palatability of coffee grounds in rations for swine, determine the digestibility and utilization of coffee grounds in swine rations and also to measure the response in terms of growth and feed efficiency when graded levels of coffee grounds were added to basic swine rations in place of grain.

Chapter II

REVIEW OF LITERATURE

The last decade has witnessed a tremendous increase in the production of instant coffee. This has accelerated the production of spent coffee grounds, a waste product which must be disposed of. The idea of feeding coffee by products to animals is not a new one. During the war of 1914-18, coffee grounds mixed with household food waste were collected and fed to livestock in many parts of Germany (Nature, 1942, p. 361). At least three companies have recently shown interest in the use of the waste product from coffee as animal feed (Feedstuff, Sept. 12, 1964), Nescafe (Production Department, Dec. 1971) and Westreco Inc. (1973).

Level of Crude Fiber

Analysis of coffee grounds gives a protein content of 11.30 percent (Deyoe, 1973). This level of protein compares favorably with grains. Amino acid composition of coffee grounds is also very similar to grain (Table VI). The questionable factor from the analysis seems to be the rather high fiber of 38.9% (Table II). Many researchers have demonstrated the inhibitory effect of high levels of dietary fiber on growth rate of growing-finishing swine (Whatley et al., 1951; Axelsson and Erickson, 1953; Coey and Robinson, 1954; Crampton et al., 1954; Teague and Hanson, 1954; Gohman et al., 1955; Merkel et al., 1953a; Jensen et al., 1959a, b; Hochstetler et al., 1959). Bohstedt and Fargo (1933) and Forbes and Hamilton (1952) provided evidence indicating that source of fiber is important in this effect.

Baird et al.(1970) conducted experiments to determine the effects of various levels of crude fiber in diets of near equal metabolizable energy on daily gain, efficiency of gain and carcass characteristics of swine. They reported a significant ($P < .05$) reduction in daily gains at the 7.5 percent fiber levels compared with a 3.5 percent level. At the 11.5 percent fiber level, feed intake was less. They observed that feed per gain ratio increased slightly, on a weight basis, with increasing fiber level from 3.5 percent to 11.5 percent fiber levels.

Pond et al. (1962) conducted trials to study the effects of crude fiber level on ration digestibility and performance in growing-finishing swine. Their results showed that low fiber (0% corn cob) rations produced significantly ($P < .01$) faster rate of gain than higher fiber (12.4% corn cob) rations. Daily feed consumption did not increase proportionately with increases in fiber content.

Hale, Johnson and Warren (1968) fed diets varying from 2.2 to 10.5 percent crude fiber with a gross energy difference from 4,446 to 3,970 kcal/kg and found gains and gain per feed ratio to be reduced at higher fiber levels. The higher fiber diets contained less energy but the pigs failed to increase consumption to compensate for the lower energy level of the diets.

Earlier Axelsson and Ericksson (1953) carried out experiments to determine the optimum crude fiber level in rations of growing pigs. They found 6.57 percent fiber to be the optimum for gain in weight with the economic optimum set at 6.64 percent. These workers also reported a slight increase in daily feed consumption with increasing fiber levels.

Level of Fat

Although rather high in fiber, coffee grounds contain 22.6 percent fat (Deyoe, 1973) which might provide enough energy for swine. Owen and

Ridgman (1967) conducted experiments to show the effect of dietary energy content on the voluntary intake of pigs. Their results showed that feed intake in the pig is primarily a function of energy content of the diet and that limited differences in energy content of the diet were not of great importance as the pig would compensate for the reduced dietary energy by increased feed consumption.

Stuart et al. (1970) at Kansas State University added levels up to 5 percent edible fat to the rations of pigs during 6 to 10 weeks of age. They reported that feed utilization favored skim milk rations with 5 percent added fat. The least efficient ration was the skim milk with no added fat. Rations containing more fat produced more efficient gains.

Allee et al. (1971) carried out experiments to determine the effects of levels of dietary fat (corn oil) on average daily gain and feed efficiency of pigs. They reported that increasing the level of dietary fat from 1 to 13 percent increased daily gain quadratically ($P < .01$). Pigs fed diets containing added fat gained significantly ($P < .01$) faster than those consuming the basal (1 percent) fat diet. There was a significant ($P < .01$) improvement in gain per feed ratio from adding fat to the diet. The pigs fed diets containing 4, 7, 10 and 13 percent dietary fat had significantly ($P < .01$) thicker average backfat than the pigs receiving the 1 percent fat diet.

Allee and Hines (1972) at Kansas State University carried out experiments to determine the influence of fat level and calorie:protein (C:P) ratio on performance and carcass composition of young pigs. They found that with a constant C:P ratio, fat level made no significant difference on daily gains, but feed efficiency improved as fat level increased. Increasing fat without adjusting the C:P ratio decreased daily

gain and metabolizable energy per unit of gain produced. With a constant C:P ratio, feeding 6 or 12 percent fat did not influence fat content of the carcass.

The results of these workers show that a high percentage of fat in the diet of swine may compensate for a high percentage crude fiber, in the production of energy.

Effects of Coffee By Products

A literature review has produced no reference in which coffee grounds were fed to swine as a source of nutrients. Few reports have been published on the effects of feeding different levels of coffee by products to other animals.

Mather and Apgar (1956) evaluated residue from soluble coffee manufacture as a feed ingredient in three studies. Both dried extracted coffee meal and CoMol (69% liquid molasses equivalent dried with coffee meal) were studied. They used sixteen Holstein cows in 4 x 4 Latin squares, 2 with coffee meal (0, 6, 12 and 18%) and 2 with CoMol (0, 8, 16 and 24%). Periods were 4 weeks and 3 weeks (one square). The authors reported no significant effect on milk production, butterfat percentage, pulse rate and flavor of the milk. Body weight of cows on coffee meal was significantly reduced. Some cows refused coffee meal or CoMol at the highest levels but 2 other cows ate up to 5.2 lb. coffee meal for 100 days without refusal or undesirable effects. Fifteen Holstein and Guernsey calves received starters containing 0, 10 or 20% CoMol from 5 to 25 weeks of age. The authors reported reduced rate of growth which could be due to lower consumption owing to poor palatability of CoMol.

Carew et al. (1967) fed diets containing solvent extracted coffee oil meal to chicks. Analysis of the coffee oil meal gave crude protein

(15.4%), crude fiber (23.7%), N.F.E. (42.9%) and ether extract (1.4%). Diets of 2.5, 5.0 and 10 percent coffee oil meal were fed to triplicate lots of 17 chicks each. Treatment 1 received the basal diet. In treatment 2, coffee oil meal replaced fine sugar in the basal diet, thus permitting increases in the total protein content of the diets, and in treatment 3, coffee oil meal replaced appropriate combinations of fine sugar and soybean meal such that total protein of this diet remained at the same level as the basal diet. The authors observed progressive depressions in growth rate as the level of coffee oil meal in the diets increased. Addition of coffee oil meal to the diet also resulted in decreased feed intake except at the low level of 2.5 percent where feed intake was similar to the basal group. Chicks converted feed into weight gain less efficiently as the level of coffee oil meal increased. The 2.5 percent level was sufficient to cause a significant reduction in weight gain. When the levels of coffee oil meal were compared no significant differences in weight gains between the two methods of substitution were observed. This indicates that the protein of coffee oil meal satisfactorily replaced soybean protein within the dietary levels studied. The high percentage of crude fiber and low percentage of ether extract indicated that coffee oil meal was of limited use in the ration of monogastric animals.

In another trial, increasing coffee oil meal to 20 percent of the diet resulted in an almost complete cessation of growth in chicks. Quite marked decreases in efficiency of feed utilization accompanied increasing dietary levels of coffee oil meal. Levels above 10 percent were toxic to chicks and a level of 20 percent resulted in up to 84 percent mortality by 4 weeks of age.

During the manufacture of instant coffee, much of the caffeine in

coffee grounds is lost. This is because of the high solubility of caffeine. The percentage caffeine in coffee grounds is rather low--about 0.075 percent (Westreco, 1973). A few researchers have fed different levels of caffeine to swine.

Cunningham (1968) showed an advantage for the use of caffeine in swine rations. He reported that caffeine increased the mobilization and oxidation of body fat in pigs, which resulted in leaner carcasses. When caffeine was included in the ration of pair fed pigs at a level of 1.5 g. per kg. of feed, it increased nitrogen retention, feed efficiency and carcass leanness. This level, however, appeared to restrict appetite and several of the pigs developed a skin rash similar to parakeratosis. All pigs developed a severe skin rash, most stopped growing and several died when the level was increased to 3.0 g. per kg. of feed. Later Cunningham (1970) conducted experiments to determine the biological half life of caffeine after injection or after various periods of ingestion. He reported that peak plasma caffeine levels were reached within 5 hr. after a single oral dose and 2 hr. after intramuscular injection and then declined with a biological half life of about 12 hours. When 1.5 g. of caffeine per kg. of feed was fed from weaning to market weight, the withdrawal of caffeine 2 days prior to slaughter was sufficient time to insure that caffeine levels in the liver, muscle, kidney and backfat were below 1 μg./g.

Cunningham (1970) carried out experiments to determine the degree to which caffeine restricts growth rate in self-fed pigs and the effectiveness of levels lower than 1.5%, in increasing leanness and feed efficiency. He also made observations on the effects of supplemental zinc, which is known to alleviate parakeratosis (Hoekstra et al., 1956; Lewis et al., 1956); calcium which may aggravate the condition (Conrad and Beeson, 1957;

Hoekstra, 1956); and corn oil, which may prevent skin scaliness in pigs (Witz and Beeson, 1951). He reported that when caffeine is added to a self-fed ration, the feed consumption of pigs is often reduced and the time required to reach market weight is increased. The degree of feed restriction depends on the amount of caffeine added to the ration and may also vary from experiment to experiment. A level of 1.5 g. of caffeine per kg. of feed increased the time for pigs to reach market weight by up to 11 days. A level of 1.0 g. caffeine per kg. of feed had no effect on growth rate. Feed efficiency was slightly (not significantly) better in the pigs receiving caffeine than those on control diet.

Feed restriction of pigs is generally accompanied by a decrease in growth rate and an increase in leanness (Brande and Townsend, 1958; Crampton et al., 1954). When a low level of 1 g. of caffeine per kg. of feed was used, the growth rate was not always restricted and the pigs were still leaner (Cunningham, 1970). The mechanism by which caffeine may cause a skin rash in pigs is not known but past studies (Cunningham, 1968; Cunningham, 1970) indicate that the rash does not appear when the dietary caffeine level is 1.0 g./kg. or less. The condition may be aggravated by high levels of compounds such as zinc and calcium. The skin rash was associated with very slow growth and the prevention of the condition by using lower levels of caffeine, although not quite as effective in increasing leanness, was probably responsible for the observed improvement in feed efficiency.

Singh et al. (1969) observed the effect of caffeine and coffee on serum cholesterol of pigs. In their study, caffeine and coffee (containing approximately an equivalent amount of caffeine) were administered intravenously and orally respectively and the effect on serum cholesterol, free

fatty acids (FFA) and triglyceride levels was observed for four hours. They reported that caffeine and coffee produced a marked rise in F.F.A., moderate elevation of triglycerides and slight decrease in cholesterol, suggesting that caffeine and coffee in some way elevate serum lipids.

Allee (1973) at Kansas State University fed growing pigs a ration containing 0.25 g. of caffeine per kg. of feed. The experiment was conducted for a 30 day period to compare the caffeine ration with one containing nicotine (200 mg. nicotine sulphate per kg. of diet), and another 4.4 mg. of diethylstilbestrol per kg. of diet. Average daily weight gain was 1.01 kg. for the pigs on nicotine, 0.91 kg. for those on the basal ration, 0.81 kg. for those on diethylstilbestrol and 0.79 kg. for the pigs on caffeine. Daily feed intake averaged 2.70 kg. for the pigs on nicotine, 2.64 kg. for those on the basal diet, 2.35 kg. for those on diethylstilbestrol and 2.07 kg. for those on the caffeine diet. Feed per gain (kg. of feed per kg. of gain) was reported to be 2.89 for the pigs on the basal diet, 2.90 for those on the diethylstilbestrol diet, 2.61 for those on caffeine diet and 2.67 for those on nicotine diet. The rates of fat synthesis of the pigs expressed as percentage of those on the basal diet were 69% for those on diethylstilbestrol, 67% for those on caffeine and 98% for those on nicotine.

Although coffee grounds have not been fed as a source of nutrients in swine diets, Hammond (1944) carried out experiments in which dried coffee grounds were compared with ground yellow corn as a source of energy in poultry diets. In his experiment the ground yellow corn was replaced by 25, 15, and 7.5 percent of dried coffee grounds. He observed that growth, efficiency of feed utilization and viability were adversely affected by feeding coffee grounds to growing chickens. Each increase in the quantity

of coffee grounds fed caused the chicks to weigh significantly less. In a second experiment conducted for the purpose of comparing coffee grounds with ground oat hulls as a diluent, ground yellow corn was replaced by 5 and 10 percent dried coffee grounds and 5 and 10 percent ground oat hulls. Even though a comparison of the chemical composition of coffee grounds and ground oat hulls indicates that the former is of far greater value than the latter as a source of energy in the diet of growing chickens, results from the experiment showed that neither 5 nor 10 percent of ground oat hulls had a deliterious effect on the chicks, but 5 percent of coffee grounds significantly decreased growth to an extent not attributable to dilution of the diet.

Barr (1972) at Kansas State University conducted feeding experiments with rats to determine the value of spent coffee grounds. In his first experiment he substituted 25, 50 and 100 percent of the protein in the basal wheat diet with protein in spent coffee grounds. Protein level of the diets was held constant at 10 percent. He found that levels greater than or equal to 25 percent of the protein supplied by coffee grounds caused a very marked decrease in feed intake with a rapid loss in weight. In a second experiment, he substituted levels of 6.25 and 12.50 percent of the protein in the basal wheat diet with protein in spent coffee grounds. The protein level of the diet was again held constant by addition of starch-glucose mixture (4:1) where necessary. The results indicated that levels as low as 6.25 percent of the protein supplied by coffee grounds also caused a marked decrease in feed intake with markedly depressing effects on growth rate.

Fat Composition of Coffee Grounds

Review of literature reveals no previous work on the analysis of the

fat composition of coffee grounds. In the present work, the fat of coffee grounds was extracted with ether. A sample of the ether extract was used to determine the types of compounds present and the fatty acids contained in the compounds using thin layer chromatography and gas chromatography respectively. The thin layer chromatography plate showed that the fat of coffee grounds contains a high proportion of triglycerides, a lower proportion of wax, fatty acids and diglycerides and a very low proportion of hydrocarbons.

A small amount of unidentified compound(s) was also shown on the chromatography plate.

The composition of the fatty acids obtained using gas chromatography is shown in Table VII.

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Chapter III

EXPERIMENTAL PROCEDURE

General Introduction

The study consisted of a growth trial, a finishing trial, a palatability study and a nitrogen retention study. The objective of the growth and finishing trials was to study the effects and utilization of five levels of coffee grounds (0, 10, 20, 30 and 40%) in diets of nursery age pigs in Trial 1, and three levels of coffee grounds (0, 10 and 20%) in diets of finishing pigs in Trial 2.

The objective of the palatability study was to study the preference of nursery age pigs when given free access to two levels of coffee grounds (0 and 20%) in their diets--Trial 3.

Feed and water were supplied ad libitum to animals on the growth trials as well as those on the palatability study. Initial and final weights were recorded and daily gain and feed efficiency were determined at the conclusion of the growth trials.

The nitrogen retention study was carried out using three levels of coffee grounds (0, 10 and 20%) in the diets--Trial 4.

All weights were taken in lbs. and converted to kg.

Facilities and Equipment

The growth trial (Trial 1) was conducted at the Kansas State University controlled environment nursery building. The facilities provided 15 pens, each 1.5 by 3.7 m. on either side of a central alley. Each pen

contained a two-hole self feeder and an automatic waterer. The floor of the nursery building is slatted. Slats are concrete, 10 cm. wide and 2.54 cm. slot between slats. Temperature was maintained at approximately 27°C. All liquid and solid wastes drop through slots into a circular manure pit below the slatted floor. An Aerob-A-Jet circulates and aerates liquid in the pit. This "aerobic oxidation" facility controls waste and odors.

The palatability study was also carried out at the same nursery building. Two larger pens 3 by 3.7 m., each pen resulting from removal of a partition between two 1.5 by 3.7 m. adjacent pens, were used for this study. Each of the two pens contained two, two-hole self feeders and two automatic waterers.

The finishing trial was conducted at the Kansas State University swine finishing building. The facilities provided 16 pens, each 1.8 by 4.9 m. with 2.5 m. alley in front of the pens. Pen floors are slatted. Slats are concrete, 10 cm. slats with 2.54 cm. slots. Liquid and solid wastes drop through slots into the manure pit below the slatted floor. Waste and odors were controlled in a manner similar to that of the nursery building. Each pen contained a two hole self feeder and an automatic waterer. Pigs were watered from electrically heated automatic waterers.

The weighing area, constructed of metal frames is adjacent to the pens. Pigs were driven along the alley to the weighing area. The entire area has concrete flooring.

A nitrogen retention study was conducted in an air conditioned house in which were six metal metabolism cages allowing for separate collection of feces and urine. The air conditioner was regulated as necessary to provide comfort for the animals.

All feeds were mixed and pelleted by the Department of Grain Science

and Industry of Kansas State University. Outgoing feed was sampled for moisture, crude protein, ash, crude fiber and fat--Table IV.

Experimental Animals

Seventy pigs, Duroc, Yorkshire and Hampshire (barrows and gilts) averaging 15-17 kg. at 6 weeks weaning age were used for the growth trial--Trial 1. Pigs were out of closely related dams. Four sires were represented but not on equal basis. Pigs were weighed on April 27, dipped in a weak solution of malathion to control possible external parasites and transferred to nursery pens. Pigs were allowed to continue on their pre-weaning ration for a twelve day adjustment period before they were introduced to the experimental diets.

Thirty-six pigs, Duroc, Yorkshire and Hampshire (barrows and gilts) averaging 51.3 kg. were used in the finishing trial. All pigs were weighed on June 20 and allotted to pens. The pigs were allowed a 28 day adjustment period before they were introduced to the experimental diets.

The palatability study involved 33 pigs, Duroc, Yorkshire and Hampshire (gilts, barrows and boars) averaging 14.2 kg.

Six Yorkshire pigs (all barrows) averaging 58.8 kg. were used for the nitrogen retention study. The six pigs were selected and used in a replicated 3 x 3 Latin square. All six pigs were weighed at the beginning and at the end of the studies.

Experimental Methods

Trial 1

Seventy Duroc, Yorkshire and Hampshire pigs (barrows and gilts) weighing 16 kg. were allotted according to weight, breed and sex to the following five treatments: (1) diet A (basal), 0% coffee grounds, (2) diet

TABLE I

COMPOSITION OF DIETS[a] - TRIAL 1

Diet	Coffee grounds (%) 0	10	20	30	40
Ingredient					
Sorghum grain	69.65	59.65	49.65	39.65	29.65
Soybean oil meal (44%)	26.60	26.60	26.60	26.60	26.60
Coffee grounds	--	10.00	20.00	30.00	40.00
Dicalcium phosphate	1.50	1.50	1.50	1.50	1.50
Limestone	.90	.90	.90	.90	.90
Salt	.50	.50	.50	.50	.50
Vitamin premix[b]	.50	.50	.50	.50	.50
Aureo-SP 250[c]	.25	.25	.25	.25	.25
Trace Mineral (Z10)[d]	.10	.10	.10	.10	.10

[a]Diets were pelleted (0.90 cm. diameter).

[b]Amount per kg: 880,000 USP Units of Vitamin A, 66,000 USP units of Vitamin D_3, 990 mgs. of Riboflavin, 2,640 mgs. of d-pantothenic acid, 66,000 mgs. of choline, 5,500 mgs. of Niacin, 4,400 I.U. of Vitamin E, 4.84 mgs. of Vitamin B_{12} and 12.54 g. preservative.

[c]Antibiotic premix.

[d]Containing 0.1% cobalt, 0.15% iodine, 20% zinc, 1.1% copper, 5.5% manganese and 10% iron.

TABLE II

PROXIMATE ANALYSIS OF COFFEE GROUNDS[a]

	Percentage	
Moisture	5.80	--
Dry Matter	94.20	100.00
Crude Protein	11.30	12.00
Crude Fiber	38.90	41.30
Ether Extract	22.60	23.99
Ash	0.55	0.58
Nitrogen Free Extract	20.85	22.13

Energy analysis of coffee grounds[b] (dry basis) for swine.

TDN, % = 15.79
D.E., (Kcal/kg.) = 696.18
M.E., (Kcal/kg.) = 651.46

[a]Proximate analysis ran at the Department of Grain Science.

[b]Energy computed using method of Regression Equation, Harris, L. E. et al. (1972).

TABLE III

COMPOSITION OF DIETS[a] - TRIAL 2

	Coffee grounds (%) 0	10	20
Ingredient			
Sorghum grain	81.8	71.8	61.8
Soybean oil meal (44%)	15.0	15.0	15.0
Coffee grounds	--	10.0	20.0
Dicalcium phosphate	1.2	1.2	1.2
Limestone	0.7	0.7	0.7
Salt	0.5	0.5	0.5
Vitamin premix[b]	0.5	0.5	0.5
Aureo-SP 250[c]	0.2	0.2	0.2
Trace Mineral (Z10)[d]	0.1	0.1	0.1

[a]Diets were in meal form.

[b]Amount per kg: 880,000 USP Units of Vitamin A, 66,000 USP units of Vitamin D_3, 990 mgs. of Riboflavin, 2,640 mgs. of d-pantothenic acid, 66,000 mgs. of choline, 5,500 mgs. of Niacin, 4,400 I.U. of Vitamin E, 4.84 mgs. of Vitamin B_{12} and 12.54 g. preservative.

[c]Antibiotic premix.

[d]Containing 0.1% cobalt, 0.15 iodine, 20% zinc, 1.1% copper, 5.5% manganese and 10% iron.

TABLE IV

TRIAL 1

ANALYSIS OF DIETS

Laboratory Analysis[a]	A	B	C	D	E
			Percentages		
Moisture	13.7	13.6	11.9	10.9	10.3
Crude Protein	17.5	19.5	18.8	19.1	19.4
Ash	5.2	5.0	5.0	4.9	4.8
Crude Fiber	2.6	5.9	9.1	11.9	15.7
Crude Fat	2.2	4.2	6.8	8.4	10.6
Calculated TDN[b]	84.7	77.4	70.1	62.8	55.4

[a]Analysis carried out at the Dept. of Grain Science and Industry.

[b]TDN = Total Digestible Nutrients.

TABLE V

TRIAL 2

ANALYSIS OF DIETS

Laboratory Analysis[a]	A	B	C
	Percentages		
Moisture	13.7	12.7	11.8
Crude Protein	15.4	15.1	15.4
Ash	5.0	4.8	4.6
Crude Fiber	2.3	6.1	8.7
Crude Fat	2.0	3.9	5.5
Calculated TDN[b]	85.2	77.9	70.6

[a]Analysis carried out at the Dept. of Grain Science and Industry.

[b]TDN = Total Digestible Nutrients.

TABLE VI

AMINO ACID COMPOSITION OF COFFEE GROUNDS[a]

Amino Acid	Percentage Composition	
	As Fed	Dry Basis
Lysine	0.214	0.227
Histidine	0.207	0.220
Arginine	0.049	0.053
Aspartic acid	0.312	0.331
Threonine	0.235	0.250
Serine	0.169	0.179
Glutamic acid	1.483	1.574
Proline	0.468	0.497
Glycine	0.529	0.562
Alanine	0.445	0.473
Half Cystine	0.043	0.046
Valine	0.570	0.605
Methionine	0.108	0.114
Isoleucine	0.403	0.428
Leucine	0.973	1.033
Tyrosine	0.349	0.371
Phenylalanine	0.546	0.580

[a]Analysis carried out at the Dept. of Grain Science and Industry.

TABLE VII

FATTY ACID COMPOSITION OF COFFEE GROUNDS[a]

Fatty Acids		Percentage
Linoleic	(18:2)	43.8
Palmitic	(16:0)	33.5
Oleic	(18:1)	8.7
Stearic	(18:0)	7.4
Arachidonic	(20:4)	3.3
Linolenic	(18:3)	1.7
Behanic	(22:0)	1.5
Myristic	(14:0)	0.1

[a]Analysis carried out using Gas Chromatography, Dept. of Biochemistry, Kansas State University.

B, 10% coffee grounds, (3) diet C, 20% coffee grounds, (4) diet D, 30% coffee grounds and (5) diet E, 40% coffee grounds. The composition of the experimental diets is shown in Table I. Coffee grounds were used as an energy source, coffee grounds replacing grain on a kg. for kg. basis. Analysis of the coffee grounds used was carried out at the Grain Science Department of Kansas State University (Table II). The trial consisted of seven pigs per pen, was replicated and lasted 35 days. All pigs were weighed at the beginning of the trial on May 8. Pigs were weighed at weekly intervals and the final weights were taken on June 12. Average feed intake, average daily gain and gain per feed ratio were calculated after each weighing. Following weekly weighing, diets C, D, and E containing 20, 30 and 40% coffee grounds respectively were readjusted after 14 days and for the rest of the period, because of palatability problem with the pigs on these diets containing high level of coffee grounds. Diets C and D were adjusted to 15 and 10% respectively and diet E was changed to control. All pigs consumed pelleted diet, 0.90 cm. diameter fed ad libitum from a two hole self feeder. Each group also had access to an automatic waterer throughout the period.

Trial 2

Thirty-six Duroc, Yorkshire and Hampshire pigs (barrows and gilts) weighing an average of 51.3 kg. were allotted according to weight, breed and sex to the following three treatments: (1) diet A (basal), 0% coffee grounds, (2) diet B, 10% coffee grounds and (3) diet C, 20% coffee grounds. Coffee grounds were used on a kg. for kg. basis, to replace grain of the basal diet as energy source. The composition of the diets is shown in Table III. The trial consisted of six pigs per pen, was replicated and lasted 49 days. The trial was carried out at the Kansas State University

finishing building. Each group consumed a meal diet, fed ad libitum from a two hole self feeder. Each group also had access to an automatic waterer. All pigs were weighed at the beginning of the trial on July 17, after a 28 day adjustment period. Pigs were weighed fortnightly, and the final weights were taken on September 4. Average daily gain, average daily feed intake and gain per feed ratio were calculated.

Four pigs were removed from each of the three diets in trial 2 when they averaged 83 kg. or above. The pigs were individually slaughtered at the Kansas State University Meat Laboratory after being held there overnight. Carcasses were dressed, weighed and then chilled for a minimum of 24 hours before carcass measurements were determined. Liver and other internal organs were inspected for possible side effects.

Trial 3

Thirty-three Duroc, Yorkshire and Hampshire (gilts, barrows and boars) weighing an average of 14.5 kg. were assigned to two 3 by 3.7 m. pens in the Kansas State University nursery building. One pen contained 18 Yorkshire pigs (barrows, gilts and boars), and the other pen contained 15 Duroc, Yorkshire and Hampshire pigs (barrows, gilts and boars). Each pen contained two, two-hole self feeders and two automatic waterers. One of the two self feeders in each pen contained diet A, 0% coffee grounds and the other contained diet C, 20% coffee grounds - Table I. The diets were pelleted (0.90 cm. diameter). The two feeders in each pen were rotated each day to prevent habit and proximity to waterers from biasing the result. Initial weights were taken on May 8 and the final weight on June 12, after a 35 day period. The intake of feed from each of the two diets were recorded at the end of the trial.

Trial 4

A nitrogen retention study was conducted using six Yorkshire barrows weighing an average of 58.9 kg. The pigs were randomly selected from 4 litters. Pigs were housed individually in metal metabolism cages allowing for separate collection of feces and urine. Two groups of three pigs were used in a Latin square design. The first group averaging 67 kg. was fed 2 kg. per day, in two equal proportions at approximately 8:00 a.m. and 5:00 p.m. The second group averaging 50.8 kg. received 1.8 kg. per day, also in two equal proportions as for the first group. A five day pre-test period followed a five day collection period. A ferric oxide marker was fed at the beginning and end of each 5-day period. Feces were collected daily and stored in a freezer. The entire 5-day fecal collection was dried in a forced-air oven at 55°C. for 6 days, allowed to come to air-dry weight, weighed and ground in a Wiley mill equipped with a 40-mesh screen. Urine was collected in an 8-liter container to which 15 ml. of concentrated HCl had been added. Collection was done at approximately 5:00 p.m. Each daily collection was diluted to a constant volume (4 liters) and a 100 ml aliquot taken. Accumulated aliquots were stored in a refrigerator until analyzed. Representative feed, fecal and urine samples were analyzed in duplicate for nitrogen as outlined by A.O.A.C. (1970), and treated statistically using analysis of variance and Ducans New Multiple Range Test (Snedecor and Cochran, 1971). The diets used for this study were: (1) diet A, 0% coffee grounds, (2) diet B, 10% coffee grounds and (3) diet C, 20% coffee grounds--Table III. Within each group, diets A, B and C were randomly assigned and fed for one period (10 days) after which treatments were re-allotted for another period. Fresh water was supplied daily as required. There were 3 periods, making it possible for each animal in each group to be fed the

three diets in randomized turn. Any feed left at the end of each collection day was collected in a polythene bag labelled and frozen. At the end of the third period, all such feed was dried in a forced-air oven at 55°C. for 6 days, allowed to come to air-dry weight and weighed. The total weighback of feed for each period was subtracted from the total feed fed to get the amount consumed during each period.

The representative samples of feed and feces from this trial were also used to analyze for dry matter, crude protein, crude fiber and ether extract to determine the digestibility. Analyses were done at the Department of Animal Science laboratories. The digestibilities were determined and treated statistically using analysis of variance and Ducan's New Multiple Range Test (Snedecor and Cochran, 1971).

Chapter IV

RESULTS

Trial 1

Results of the growth trial are presented in Tables VIII, IX and X. A level of coffee grounds as low as 10% depressed average total gain significantly ($P < .01$) during the initial 14 day period. There was progressive depression of average total gain with increasing levels of coffee grounds. A level as high as 40% coffee grounds in the diet resulted in negative average total gain and gain/feed ratio. A level of 10% coffee grounds in the diets depress total daily feed intake and gain/feed ratio, but not significantly ($P < .05$). However, total daily feed intake and gain/feed ratio were significantly ($P < .05$) depressed at levels above 10% coffee grounds--Table VIII.

Change of diets from 20, 30 and 40% coffee grounds to 15, 10 and 0% levels respectively during the last 21 days of the trial resulted in improved performance of the growing pigs. Average total gain, total daily feed intake and gain/feed ratio were significantly ($P < .05$) improved--Table IX.

Results of the 0 and 10% coffee grounds for the entire 35 day period are presented in Table X. Total daily feed intake and gain/feed ratio were depressed, but not significantly ($P < .05$). However, average total gain was significantly ($P < .01$) depressed with the level of 10% coffee grounds in the basal diet. None of the pigs showed any sign of skin rash.

TABLE VIII

TRIAL 1

PERFORMANCE OF GROWING PIGS FED GRADED LEVELS OF COFFEE GROUNDS[a]

Diets	Average total gain (kg)	Total daily feed intake[b] (kg)	Gain/Feed
1. Basal, 0% coffee grounds	7.44[c]	14.61[g]	0.51[g]
2. 10% coffee grounds	5.10[d]	12.44[g]	0.41[g]
3. 20% coffee grounds	0.94[e]	7.47[h]	0.13[h]
4. 30% coffee grounds	0.07[ef]	6.00[h]	-0.01[h]
5. 40% coffee grounds	-1.10[f]	4.68[h]	-0.26[i]

[a]14 day summary.

[b]14 pigs per diet, ave. initial weight, 16 kg.

[cdef]Means with different superscript in the same column are significantly different ($P < .01$).

[ghi]Means with different superscript in the same column are significantly different ($P < .05$).

TABLE IX

TRIAL 1

PERFORMANCE OF GROWING PIGS FOLLOWING CHANGE OF DIETS[a]

	Diets % Coffee Grounds 1st 14 days	last 21 days	Average total gain (kg)	Total daily feed intake[e] (kg)	Gain/Feed
1.	0	0	13.60^{bc}	19.61^{c}	0.46^{bc}
2.	10	10	12.08^{b}	18.01^{c}	0.45^{bc}
3.	20	15	9.55^{d}	16.08^{c}	0.40^{b}
4.	30	10	10.26^{d}	16.19^{c}	0.42^{b}
5.	40	0	14.06^{c}	19.22^{c}	0.49^{c}

[a]Three of the diets were changed after 14 days; analysis covers last 21 days following change of diets.

[bcd]Means with different superscript in the same column are significantly different ($P < .05$).

[e]14 pigs per diet, average initial weight, 16 kg.

TABLE X

TRIAL 1

PERFORMANCE OF GROWING PIGS FED GRADED LEVELS OF COFFEE GROUNDS[a]

Diets	Average total gain (kg)	Total daily feed intake[b] (kg)	Gain/Feed
1. Basal, 0% coffee grounds	21.04[c]	17.61[c]	0.48[c]
2. 10% coffee grounds	17.73[d]	15.78[c]	0.45[c]

[a]35 day summary of the 0% and 10% levels.
[b]14 pigs per diet, average initial weight, 16 kg.
[cd]Means with different superscript in the same column are significantly different ($P < .01$).

TABLE XI

TRIAL 2

PERFORMANCE OF FINISHING PIGS FED GRADED LEVELS OF COFFEE GROUNDS[a]

Diets[b]	Average daily gain (kg)	Average daily feed intake (kg)	Gain/Feed
1. Basal, 0% coffee grounds	0.74[c]	2.47[c]	0.30[c]
2. 10% coffee grounds	0.65[c]	2.32[c]	0.28[c]
3. 20% coffee grounds	0.37[d]	1.68[d]	0.22[d]

[a]49 day trial.
[b]12 pigs per diet, average initial weight 51.3 kg.
[cd]Means with different superscript in the same column are significantly different ($P < .05$).

TABLE XII

TRIAL 2

EFFECTS OF LEVELS OF COFFEE GROUNDS ON CARCASS CHARACTERISTICS[a]

Items	Level of coffee grounds 0%	10%	20%
1. Carcass length, in.	30.43[b]	30.98[b]	30.25[b]
2. Loin eye area, sq. in.	4.36[b]	4.62[b]	3.94[b]
3. Ave. carcass backfat, in.	1.25[b]	1.07[b]	0.85[b]
4. Ham and loin, %	40.64[b]	42.18[b]	42.82[b]

[a]Data were collected from 4 barrows in each treatment; average weight, 89.2 kg.

[b]Means on the same line with the same superscript are not significantly different ($P < .05$).

Trial 2

Results of the finishing trial are shown in Table XI. A level of 10% coffee grounds in the diets depressed average daily gain and average daily feed intake but not significantly ($P < .05$). There was also no significant difference ($P < .05$) in gain/feed ratio between the 0 and 10% levels of coffee grounds. However, the pigs on the diet containing 20% coffee grounds gained significantly ($P < .05$) less, consumed less feed per day and consumed more feed per unit gain.

When 4 barrows were slaughtered from each of the three treatments (0, 10 and 20% coffee grounds), there were no significant ($P < .05$) differences in carcass length, loin eye area, average carcass backfat and ham and loin percentage between the treatments--Table XII. The liver and other internal organs inspected were normal.

Trial 3

The results of the palatability study are shown in Table XIII. Pigs that had access to diets containing both 0 and 20% coffee grounds throughout the 35 day period exhibited a continued preference for the diet containing no coffee grounds by consuming significantly ($P < .01$) more of it.

Trial 4

The results of the nitrogen retention study are shown in Table XIV. There was no difference in nitrogen retention between the 0 and 10% coffee diets. A level of 20% coffee grounds in the diet decreased nitrogen retention significantly ($P < .05$).

The results of the digestion studies are shown in Table XV. There was progressive depression in digestibility of the dry matter, crude protein and crude fiber with increasing levels of coffee grounds in the diets.

However, the digestibility of ether extract improved, though not significantly as levels of coffee grounds increased ($P < .05$). A level of 10% coffee grounds in the diet depressed digestibility of dry matter, crude protein and crude fiber significantly ($P < .05$). Increasing the level of coffee grounds to 20% further depressed digestibility.

TABLE XIII

TRIAL 3

RESULT OF PALATABILITY STUDY

Diets	Total feed intake[a] (kg)
1. 0% coffee grounds	1135.00[b]
2. 20% coffee grounds	27.73[c]

[a]35 day feeding period; average initial weight 14.5 kg.

[bc]Means with different superscript in the same column are significantly different ($P < .01$).

TABLE XIV

TRIAL 4

NITROGEN RETENTION OF PIGS FED GRADED LEVELS OF COFFEE GROUNDS[a]

Diets	Daily N(g) Intake	Urine	Fecal	Retained
1. Basal, 0% coffee grounds	41.35	14.55	8.02	18.78[b]
2. 10% coffee grounds	43.57	13.25	11.12	19.20[b]
3. 20% coffee grounds	41.83	11.05	14.08	16.70[c]

[a]Six Yorkshire barrows weighing 60.2 kg., 3 x 3 Latin square.

[bc]Means with different superscript in the same column are significantly different ($P < .05$).

TABLE XV

TRIAL 4

RESULTS OF DIGESTION STUDIES[a]

Diets	% Digestibility			
	Dry Matter	Crude Protein	Crude Fiber	Ether Extract
1. Basal, 0% coffee grounds	88.07[b]	80.70[b]	67.29[b]	44.94[b]
2. 10% coffee grounds	80.29[c]	73.13[c]	35.28[c]	50.74[b]
3. 20% coffee grounds	75.50[d]	66.17[d]	27.72[d]	52.64[b]

[a]Six Yorkshire barrows weighing 60.2 kg. 3 x 3 Latin square.
[bcd]Means with different superscript in the same column are significantly different ($P < .05$).

Chapter V

DISCUSSION

The result of these trials indicate that coffee grounds cannot be used to any high degree as a grain replacement in rations for swine. Trial 1 revealed that level of coffee grounds greater than 10% caused a very significant decrease in feed intake, weight gain and feed efficiency (gain/feed ratio) of growing pigs. This result is similar to an earlier result obtained when Hammond (1944) used 15 and 25% coffee grounds to replace ground yellow corn in poultry diets. In the present studies, as low as 10% coffee grounds in the diet was shown to have a depressing effect on feed intake, weight gain and feed efficiency. However the depressing effect on feed intake and feed efficiency was not significant at this level. The results also show that a level as high as 30% coffee grounds caused the animals to lose weight. No pigs were lost during the 14 day initial period and also following the change in diets. Carew et al. (1967) postulated that coffee oil meal was toxic to chicks at levels of 10% or more in the diet. Apparently, the depressing effect on growth rate in the present studies was due to lack of palatability rather than any toxic factor in the diets. This follows from the fact that after changing the diets following the initial 14 day period (Tables VIII & IX), the pigs previously fed 20, 30 and 40% coffee diets significantly improved their feed intake, weight gain and feed efficiency.

The results of Trial 2 with finishing pigs are similar to those with growing pigs. Apparently, the palatability problem which limited the

utilization of high levels of coffee grounds in growing pigs also affected the finishing pigs. Feed intake, rate of gain and feed efficiency decreased with increasing levels of coffee grounds. Barr (1972) held protein level constant at 10% in diets for rats. He observed that levels greater than or equal to 25% of the protein supplied by coffee grounds caused a marked decrease in feed intake with a rapid loss in weight. In the present studies, the depression was not significant at the level of 10% coffee grounds, but it was very significant at the level of 20% (Table XI).

The progressive decrease in feed intake of the diets containing increasing levels of coffee grounds explains why the pigs lost weight in Trial 1 and why feed efficiency decreased as the level of coffee grounds increased. Pigs did not consume enough feed to meet their maintenance requirements due to poor palatability of coffee grounds. Owen and Ridgman (1967) showed that feed intake in the pig is primarily a function of energy content of the diet. The calculated TDN values of the diets in the present studies show that coffee grounds are comparatively lower in energy than sorghum grains. As increasing levels of coffee grounds were added to the diets, the TDN values of the feeds decreased (Tables IV and V).

Another explanation for the poor utilization of the diets containing high levels of coffee grounds could be attributed to increasing levels of crude fiber in the diets as percentage coffee grounds in the diets increased. Diet B (10% coffee grounds), containing 5.9% crude fiber (Table IV) did not show significant depression in feed utilization and rate of growth when compared to the basal diet (2.6% crude fiber). However, diets C, D and E containing 9.1, 11.9 and 15.7% crude fiber respectively showed very significant depression in feed intake, growth rate and feed efficiency.

This supports earlier experiments of Axelsson and Ericksson (1953) in which they found 6.57% crude fiber to be optimum for gain in weight in growing pigs. Pond et al. (1962) showed that low fiber rations produced significantly faster rate of gain than higher fiber rations. Although analysis of the experimental diets (Table IV) suggests that coffee grounds might be a useful ingredient in ration for swine, digestibility studies showed a depression in the digestibility of dry matter, crude protein and crude fiber as level of coffee grounds in the diets increased ($P < .05$). This depression might be attributed to a lower digestion coefficient of the dry matter, crude protein and crude fiber of coffee grounds than those of sorghum grains. This suggests that coffee grounds are of poorer quality as an energy source in rations for swine than sorghum grains. Improvement in ether extract digestibility observed could be due to the fair amount of useful fatty acids in the ether extract (Table VII). Only at very low levels can coffee grounds be expected to replace sorghum grains. Apparently, the presence of coffee grounds in the diets has no effect on internal organs.

This study showed no significant difference in nitrogen retention between the basal and 10% coffee diet (Table XIV). A level of 20% coffee in the diet however, depressed nitrogen retention significantly. This shows that coffee grounds though relatively high in crude protein and containing amino acids in amounts comparable to sorghum grains, have a poorer nitrogen retention value. This further limits the use in swine rations.

SUMMARY

A growth trial, a finishing trial, a palatability study and a nitrogen retention study were conducted with 112 pigs to determine the usefulness of coffee grounds as a grain replacement in rations for growing finishing pigs. The levels of coffee grounds used were 0, 10, 20, 30 and 40% with the growing pigs and 0, 10 and 20% with the finishing pigs. As little as 10% coffee grounds in the diet resulted in a depression in feed intake and feed efficiency in both the growing and the finishing pigs. This decrease was not however high enough to be statistically significant. Level as high as 20% coffee grounds or more caused a very significant depression in feed intake, rate of gain and feed efficiency.

Apparently, the depressing effect of the coffee diets was not due to any toxic factor in the diet. The pigs did recover when the percentage of coffee grounds in their diet was lowered. Nitrogen retention and the digestibility of dry matter, crude protein and crude fiber decreased with high levels of coffee grounds in the diets.

The levels of coffee grounds studied suggest that coffee grounds cannot be used efficiently at a level higher than 10% as a grain replacement in rations for swine. It appears that a lower level could be added successfully.

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COFFEE GROUNDS AS A GRAIN REPLACEMENT IN RATIONS FOR GROWING-FINISHING PIGS

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ABSTRACT

A growth trial, a finishing trial, a palatability study and a nitrogen retention study were conducted to determine the usefulness of coffee grounds, resulting from the preparation of soluble coffee, as a grain replacement in rations for growing and finishing pigs. Kansas State University buildings and facilities were used for all the studies.

The levels of coffee grounds used were 0, 10, 20, 30 and 40% for the growing pigs and levels of 0, 10 and 20% for the finishing pigs. Coffee grounds replaced sorghum grains in the diets, on a kg. for kg. basis as an energy source. A level of coffee grounds as low as 10% depressed average total gain significantly ($P < .05$). However the depressing effect was not significant for the total daily feed intake and gain/feed ratio ($P < .05$). Higher levels of coffee grounds have a significant depression on the general performance of the growing pigs ($P < .05$). A level of 10% coffee grounds in the diets of finishing pigs also showed a non significant ($P < .05$) depression on average daily feed intake, average daily gain and gain/feed ratio.

Apparently, reduced performance of the pigs fed coffee diets was due to lack of palatability rather than any toxic factors in the diets. When pigs were given access to diets containing both 0 and 20% coffee diets, they exhibited a continued preference for the 0% coffee diet. Also when three of the diets (20, 30 and 40%) in the growth trial were changed because of poor performance following an initial 14 day period, and the percentage coffee grounds in the diets reduced, performance of the pigs was significantly ($P < .05$) improved.

The nitrogen retention study showed no difference in nitrogen retention between the 0 and 10% coffee grounds in the diet, but a level as high as 20% coffee grounds in the diet decreased nitrogen retention significantly ($P < .05$). There was progressive depression in digestibility of the dry matter, crude protein and crude fiber with increasing levels of coffee grounds in the diet. A level as low as 10% coffee grounds in the diet depressed digestibility of dry matter, crude protein and crude fiber significantly ($P < .05$).

These results show that coffee grounds though relatively high in ether extract and crude protein, and containing amino acids in amounts comparable to grains, are of poorer quality as an energy source in rations for swine than sorghum grains.