EFFECT OF COCONUT MEAL ON COTURNIX QUAIL AND OF COCONUT MEAL AND COCONUT OIL ON PERFORMANCE, CARCASS MEASUREMENTS AND FAT COMPOSITION IN SWINE [1]

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A LACK of available feedstuffs, especially protein sources, is the greatest factor limiting swine production throughout most of the tropics. Coconut meal, a by-product of the occonut oil industry, is often available. Although the protein content of this product (21%) is less than that of feeds commonly used for protein supplementation, it represents the largest quantity of locally available feed protein in many areas. Diverse beliefs exist regarding the effect of coconut meal in swine diets. A literature review leads to the conclusion that knowledge of the value of coconut meal is insufficient. Mitchell and Villegas (1923), Smuts and Malan (1938), Mitchell, Hamilton and Beadles (1945) and Loosli *et al.* (1954) reported that the protein may be low in both digestibility and of poor biological value. Few data are available to indicate the effect of coconut oil on swine performance or pork fat composition. The foregoing studies were undertaken to determine the effect of various levels of coconut meal on the growth of quail (*Coturnix c. japonica*) and the effect of coconut meal and coconut oil on performance of growing swine, the limiting factors present in coconut meal and the effects of coconut oil and coconut meal on carcass measurements and fat composition of swine.

Experimental Procedure

One-hundred-fifty quail were used in a pilot study to determine the effect of level of coconut meal (0, 20, and 40%) with and without L-lysine-HCl supplementation in isonitrogenous (1.38% N) sugar- or corn-base diets on gains. The experimental plan and diet composition are shown in table 1. When birds were 3 weeks of age and averaged 40 g, they were randomly assigned, 15 per treatment, and fed for 26 days. Gains were calculated and analyzed by sex. The mean of the two sexes is presented as the gain for the lot.

In trial 1, 64 crossbred pigs averaging 18 kg were randomly assigned to treatments from outcome groups. Outcome groups were made up of pigs with similar breeding, age and weight. The factorial arrangement of treatments provided for four levels of coconut meal (0, 10, 20 and 40%), two levels of coconut oil (0 and 10%) and two sexes (gilts and barrows). The two sexes were fed together.

The composition of diets fed until pigs averaged 34 kg is shown in table 2. Protein levels were then reduced by 2 percentage points. The eight diets were calculated to have the same protein: calorie ratio, thus the four with 10% coconut oil were higher in protein content. Bagasse pith was used as an inert substance to make the four diets within each fat level isocaloric.

Thirty pigs with similar weight, breeding and management background as those of trial 1 were used in trial 2. This trial was designed to supply approximately the same quantity of available lysine in diets containing 20 and 40% coconut meal. This quantity was calculated to be slightly above that of the basal corn-soybean meal diet. The lysine was supplied either by increasing the protein level of the diet through an adjustment of the ratio of corn to soybean meal or by adding L-lysine HCl. Energy adjustments to maintain isocaloric diets were made by varying the ratio of fat in the diet. The composition diets that were fed until pigs averaged 34 kg is presented in table 3.

Pigs were weighed at 2-week intervals until near slaughter weight when they were weighed weekly. Each pig was removed for slaughter when its weight exceeded 77 kilogram. They were dressed modified-shipper style with the breast bone intact and the head on. After a 24-hr. chill, the head was removed and the carcasses were split. Data collected were for backfat thickness, carcass length and area of the *longissimus dorsi* (loin eye) at the 10th rib according to the procedure set forth by the pork carcass committee of the Reciprocal Meat Conference (National Livestock and

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TABLE 1. COMPOSITION OF DIETS FED TO QUAIL

Ingredient[a]	Sugar base				
Coconut meal	0.00	20.00	40.00	20.00	40.00
Sugar	44.45	34.05	23.55	34.05	23.55
Soybean meal	45.10	35.50	26.00	35.50	26.00
Tuna meal	3.00	3.00	3.00	3.00	3.00
Dehydrated alfalfa meal	3.00	3.00	3.00	3.00	3.00
Dicalcium phosphate	3.60	3.60	3.60	3.60	3.60
Trace mineral salt[b]	0.25	0.25	0.25	0.25	0.25
Vitamin mix[c]	0.50	0.50	0.50	0.50	0.50
DL-methionine	0.10	0.10	0.10	0.10	0.10
L-Lysine · HCl	0.00	0.00	0.00	0.18	0.36
	Corn base (only ingredients that differ from above)				
Corn	55.10	41.80	28.30	41.80	28.30
Soybean meal	34.30	27.60	21.10	27.60	21.00
Dicalcium phosphate	3.75	3.75	3.75	3.75	3.75

[a] Percent of air dry diet.
[b] Provided following kilogram of diet: 2.4 g NaCl, 13 mg Zn, 10 mg Mn, 2 mg Fe, 1 mg Mn and 0.2 mg Cu.
[c] Provided following per kilogram of diet: 12,000 IU vitamin A, 3,300 IU vitamin D, 2.2 IU vitamin E, 2 mg menadione sodium bisulfate complex, 8.5 mg riboflavin, 12.5 mg d-pantothenic acid, 4.4 mg niacin, 440 mg choline chloride and 13 μg vitamin B_{12}.

Meat Board, 1952). In the first trial, the ham was removed from the right side of the carcass by cutting between the second and third sacral vertebra and perpendicular to the shank. The foot was removed by cutting between the tarsals and the tibia-fibula. This constituted the untrimmed ham which was physically separated into fat plus skin, muscle and bone.

Backfat samples representing a cross-section of backfat were taken at a point even with the tenth rib from pigs that had received 0, 20, or 40% coconut meal diets. Approximately 2 g adipose tissue was ground in a mortar and pestle containing anhydrous ether. The ether was evaporated from a refluxing flask over a water bath at 50 C. Methyl esters were prepared from the fat by refluxing for 1 hr. in methanol with a sulfuric acid catalyst according to the procedure of Hilditch (1956). The methyl esters were then taken up in petroleum ether before injections into an Aerograph Model A/600 gas chromatograph containing a 1.52 m x 0.31 cm stainless steel column packed with 20% diethyleneglycol succinate and 5% isopthalic acid on 60/80 hexamethyldisilazane treated chromosorb W(HMDS). Peak areas for lauric (C_{12}), myristic (C_{14}), palmitic (C_{16}), palmitoleic (C_{16}=1), stearic (C_{18}), oleic (C_{18}=1) and lineoleic (C_{18}=2) acids were obtained after injecting methyl

TABLE 2. COMPOSITION OF DIETS FED TO PIGS TO 34 KG LIVE WEIGHT (SWINE TRIAL 1)

Ingredient[a]	16% protein without added coconut oil				17.5% protein with 10% coconut oil			
Coconut meal	0.00	10.00	20.00	40.00	0.00	10.00	20.00	40.00
Coconut oil	0.00	0.00	0.00	0.00	10.00	10.00	10.00	10.00
Raw sugar	59.68	55.28	51.08	42.38	45.26	40.96	36.76	28.06
Soybean meal (44%)	29.40	24.80	20.10	10.80	33.70	29.00	24.30	15.00
Tuna meal	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Bagasse pith	4.10	3.10	2.00	0.00	4.10	3.10	2.00	0.00
Trace mineral salt[b]	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Vitamin premix[c]	0.25	0.25	0.25	0.25	0.28	0.28	0.28	0.28
Antibiotic supplement[d]	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Methionine	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Dicalcium phosphate	0.77	0.77	0.77	0.77	0.86	0.86	0.86	0.86
Chemical analysis, %								
Moisture	5.2	4.8	5.9	5.8	5.5	5.7	6.2	6.6
Crude protein	16.2	15.8	16.2	15.8	17.6	17.8	17.5	17.0
Ether extract	1.2	1.4	2.2	6.6	10.3	11.2	11.8	12.7
Ash	5.3	4.8	6.0	6.2	5.0	5.7	5.6	5.3
Crude fiber	3.3	3.5	4.4	4.5	3.7	4.0	4.5	5.5
N.F.E.	68.8	69.7	65.3	65.1	57.9	55.6	54.4	52.9

[a] Percent of air dry diet.
[b] Provided the following per kilogram of diet: 4.9 g NaCl, 22 mg Mn, 25 mg Zn, 10 mg Fe, 1.6 mg Cu and 0.3 mg I.
[c] Provided the following per kilogram of diet: 3,300 IU vitamin A, 1,100 IU vitamin D, 2.2 mg vitamin E, 4.4 mg riboflavin, 8.1 mg d-pantothenic acid, 22 mg niacin, 110 mg choline chloride, 12 μg vitamin B_{12} and 125 mg B.H.T.
[d] Each kilogram contained 22 g chlortetracycline.

TABLE 3. COMPOSITION OF DIETS—TRIAL 2

Ingredients[a]	Basal	High protein		Lysine supplemented	
Coconut meal	0.00	20.05	40.00	20.00	39.49
Ground shelled corn	77.80	55.95	34.00	60.90	45.35
Soybean meal (44%)	13.00	13.00	13.00	7.90	1.90
Tuna meal	5.00	5.00	5.00	5.00	5.00
Fat (yellow grease)	2.00	4.00	6.00	4.00	6.00
Trace mineral salt[b]	0.50	0.50	0.50	0.50	0.50
Ground limestone	0.50	0.65	0.65	0.65	0.65
Tricalcium phosphate	0.60	0.25	0.25	0.25	0.25
Vitamin premix[c]	0.25	0.25	0.25	0.25	0.25
Antibiotic supplement[d]	0.10	0.10	0.10	0.10	0.10
DL-methionine	0.25	0.25	0.25	0.25	0.25
L-Lysine • HCl	0.00	0.00	0.00	0.20	0.26
Protein (N x 6.25)	15.8	18.1	20.4	16.0	16.0
Lysine % of feed	0.744	0.831	0.886	0.891	0.830
Digestible lysine of feed[e]	0.697	0.717	0.718	0.761	0.667
Lysine as % of need[f]	111	101	95	121	106

[a] Percent of air-dry diet.
[b] Provided the following per kilogram of diet: 4.9 g NaCl, 22 mg Mn, 25 mg Zn, 10 mg Fe, 1.6 mg Cu and 0.3 mg I.
[c] Provided the following per kilogram of diet: 3,300 IU vitamin A, 1,100 IU vitamin D, 2.2 mg vitamin E, 4.4 mg riboflavin, 8.1 mg d-pantothenic acid, 22 mg niacin, 110 mg choline chloride, 12 μg vitamin B_{12} and 125 mg B.H.T.
[d] Each kilogram contained 22 g chlortetracycline.
[e] Calculated using N.R.C. composition and current digestibility of protein for availability.
[f] Calculated from lysine requirement as it varies with protein level (Becker *et al.*, 1957).

esters by using a disc chart integrator. Retention time on the column was the criterion used for identifying the various fatty acids.

The data were analyzed by analyses of variance and the multiple range test (Duncan, 1955) was used to locate significant differences between treatment means. For the analysis on daily gain and physical composition of the ham, covariance analysis was used to adjust for differences in initial weight and carcass weight, respectively.

Results and Discussion

Female quail gained an average of 82 g while males gained an average of 56 g ($P < .01$). There were no significant interactions between level of coconut meal and sex. Inclusion of 40% coconut meal in corn base diets resulted in a significant ($P < .05$) increase in 26-day gains compared to those obtained when such diets contained 0 or 20% coconut meal. When data for both types of base diets were combined, 40% coconut meal resulted in significantly ($P < .05$) larger gains than 0 meal (table 4). The addition of lysine also resulted in significant differences ($P < .05$) between combined gains. The cause of this greater gain from added coconut meal is not clear except that greater fill may have occurred due to the greater feed intake. The addition of meal resulted in depressing the calculated available energy content of the diet. This was reflected in the greater daily feed intake and the decreased feed/gain ratio. Birds fed the sugar base diets gained faster

TABLE 4. EFFECT OF COCONUT MEAL WITH AND WITHOUT SUPPLEMENTAL LYSINE ON GAINS OF QUAIL

Coconut meal, T L-lysine HCl, %	0 ..	20 ..	40 ..	20 0.18	40 0.36	Average
			Sugar base diets			
26-day gain, g	65.7[a]	70.0[ab]	68.4[ab]	69.0[ab]	74.1[b]	69.4
Feed intake/day, g	10.9	12.1	13.2	11.7	14.8	12.5
Feed/gain	4.3	4.5	5.0	4.4	5.2	4.7
			Corn base diets			
26-day gain, g	64.9[a]	65.3[a]	69.9[b]	67.3[ab]	70.3[b]	67.5
Feed intake/day, g	10.0	11.3	13.7	11.6	13.5	12.0
Feed/gain	4.0	4.5	5.1	4.5	5.0	4.6
			Combined gains			
Avg gain, g	65.3[a]	67.6[ab]	69.2[b]	68.2[b]	72.2[c]	68.5

[a, b, c] For a single criterion, values on the same horizontal line having the same or no superscript letters are not significantly different ($P < .05$) (Duncan, 1955).

TABLE 5. EFFECT OF SEX, COCONUT OIL AND COCONUT MEAL ON RATE AND EFFICIENCY OF GAIN AND CARCASS CHARACTERISTICS OF SWINE (TRIAL 1)

Treatment	No. of pigs	Avg daily gain	Feed/ gain	Daily feed intake	Dressing %	Carcass length	Backfat thickness	Loin eye area
		kg	kg	kg		cm	cm	cm²
Sex								
Barrows	32	0.68[a]	....	....	75.1	71.1[a]	3.02	24.5[a]
Gilts	32	0.63[b]	....	....	77.2	72.6[b]	3.00	26.8[b]
Coconut oil								
0%	32	0.63[a]	3.00	1.88	75.8	71.9	3.05	22.4
10%	32	0.67[b]	2.61	1.69	76.7	71.6	3.12	25.9
Coconut meal								
0%	16	0.76[a]	2.51	1.88	76.1	72.1	3.12	27.1[a]
10%	16	0.74[a]	2.68	1.97	76.6	70.9	3.18	26.9[a]
20%	16	0.65[b]	2.75	1.80	75.5	71.1	2.82	25.5[a]
40%	16	0.46[c]	3.27	1.49	77.0	72.6	3.25	22.3[b]

[a, b, c] For a single criterion, values on the same vertical column having the same or no superscript letters are not significantly ($P<.05$) different (Duncan, 1955).

($P<.05$) than those fed the corn base diets but no significant interactions were found between base diets x coconut meal inclusions or between the base diets x sex.

Data on performance and carcass measurements from trials 1 and 2 with swine are shown in tables 5 and 6, respectively. The inclusion of coconut meal in the diets decreased rate and efficiency of gain ($P<.05$) in both trials. There were no coconut meal x coconut oil treatment interactions; therefore, these data were combined. The decrease in rate of gain when either 20 or 40% meal was included was significant ($P<.05$). In trial 2, only the decrease due to 40% coconut meal was significant.

The poor performance of pigs fed diets containing 20 and 40% coconut meal in trial 1 may have been due to low digestibility of protein or low lysine level. Neither increasing the protein level to a point assuring equal protein and lysine availability nor supplementing with lysine at a level to insure adequacy of this amino acid in trial 2 resulted in gains, feed/gain ratio or carcass measurements comparable to those obtained when the corn-soybean meal type basal diet was fed. This is in contrast to the results of Brooks and Thomas (1959) in which the addition of lysine to a corn-peanut meal diet restored normal growth, feed/gain and carcass leanness. It appears, therefore, that low digestibility of protein or low lysine is not the complete cause of unsatisfactory results from diets containing high levels of coconut meal. The reason for the species difference in response to coconut meal in the diet is not clear.

Loin-eye area of pigs decreased due to the inclusion of coconut meal in the diet in both trials. This depression was not overcome by increased protein level or by adding lysine in trial 2. Further evidence of depression in muscle mass due to coconut meal is shown in table 7 where the addition of 40% coconut meal resulted in depression ($P<.05$) of ham weight and further that most of this depression in weight was due to decreased lean or muscle. This depression in

TABLE 6. EFFECT OF INCREASING PROTEIN LEVEL AND LYSINE SUPPLEMENTATION OF SWINE DIETS THAT ARE HIGH IN COCONUT MEAL ON RATE AND EFFICIENCY OF GAIN AND CARCASS MEASURES (TRIAL 2)

Level of coconut meal, %	None	20	40	20	40
Protein, %[a]	15.8	18.1	20.4	16.0	16.0
L-lysine (HCl) supplement, %	....	....	....	0.20	0.26
No. pigs	6	6	6	6	6
Avg daily gain, kg	0.69[b]	0.65[bc]	0.58[c]	0.64[bc]	0.55[c]
Feed/gain	2.80	3.06	3.29	2.99	2.97
Carcass length, cm	74.5	73.0	72.6	73.8	73.4
Backfat thickness, cm	2.92	3.00	2.82	3.05	3.02
Loin eye area, cm²	28.8[b]	26.2[c]	25.2[c]	24.5[c]	21.9[d]

[a] Protein level represents level fed to pigs up to 34 kg live weight.
[b, c, d] For a single criterion, values on the same horizontal line having the same superscript letters are not significantly different ($P<.05$) (Duncan, 1955).

TABLE 7. EFFECT OF SEX AND COCONUT MEAL ON PHYSICAL COMPOSITION OF THE HAM (TRIAL 1)

Item	Ham weight	Lean weight	Fat weight	Bone weight
	kg	kg	kg	kg
Sex				
Barrows	6.42	4.06	1.65	0.66
Gilts	6.48	4.03	1.77	0.66
Coconut meal				
0%	6.74[a]	4.40	1.69	0.65
10%	6.50[a]	4.03	1.81	0.64
20%	6.57[a]	4.16	1.77	0.64
40%	6.09[b]	3.60	1.79	0.68

[a, b] For a single criterion, values in the same vertical column having the same or no superscript letters are not significastly ($P<.05$) different (Duncan, 1955).

muscle size may be indicative of an amino acid deficiency. Such a deficiency might be the result of an inadequate level or low availability. Adding coconut meal did not significantly affect other carcass measurements in either trial nor did it significantly alter the ham fat or bone weight in trial 1.

The rate of gain of barrows in trial 1 was greater ($P<.05$) than that of gilts. This is in agreement with Blair and English (1965) and Tribble *et al.* (1965) who found that barrows gained faster than gilts. Gilts on the other hand were longer and had larger loin eye areas ($P<.05$) than barrows in trial 1. In trial 2, the only difference between sexes was the significant difference in loin-eye area.

The addition of 10% coconut oil in trial 1 resulted in increased rate of gain ($P<.05$) (0.63 to 0.67 kg daily) and decreased feed/gain (3.00 to 2.61). Comparable increases were reported by Blumer *et al.* (1957) and Clawson *et al.* (1962) when other fats were added to swine diets. The addition of oil did not significantly alter carcass measurements or physical composition of the ham.

Fatty acid composition of backfat as affected by the addition of 10% coconut oil or 20 and 40% coconut meal to the diet is presented in table 8. The fatty acid composition of the coconut oil is also shown in this table. The fat of pigs fed the diets containing 10% coconut meal was not analyzed. The addition of 10% coconut oil to the diet caused increases ($P<.05$) in lauric (C_{12}), myristic (C_{14}), palmitic (C_{16}) and palmitoleic ($C_{16}=1$) with a consequent decrease in oleic ($C_{18}=1$) acid of the backfat. These changes represent a relative increase in the proportion of saturated over unsaturated fatty acids. While the levels of lauric and myristic acids increased in pork fat when coconut oil was fed, they still constituted only a small proportion of the total fatty acids in the backfat of pigs fed this high level of oil, considering that they constitute more than 60% of the fatty acids of coconut oil. Likewise, caprylic (C_8) and capric (C_{10}) acids make up a rather high percentage (25.1%) of the fatty acids in coconut oil while only traces were found in the backfat of pigs receiving the oil. These results are in agreement with those reported by Christensen (1963) and Chung and Lin (1965) who reported that these acids were not readily utilized in the formation of fat tissue in swine. Addition of coconut oil resulted in no significant changes in the percentages of stearic (C_{18}) and linoleic ($C_{18}=2$) acids in pork fat.

The addition of coconut meal to the diet also caused increases in the percentages of

TABLE 8. EFFECT OF COCONUT OIL AND COCONUT MEAL ON THE FATTY ACID COMPOSITION OF BACKFAT (SWINE TRIAL 1)

Treatment	Percentage composition of fatty acids								
	C8	C10	C12	C14	C16	$C16^{=1}$	C18	$C18^{=1}$	$C18^{=2}$
	Composition of pork fat								
Coconut oil									
0%	Trace	Trace	0.6[a]	2.6[a]	24.3[a]	4.9[a]	11.8	51.7[a]	3.4
10%	Trace	Trace	4.1[b]	9.6[b]	27.7[b]	6.2[b]	11.6	37.2[b]	3.5
Coconut meal									
0%	Trace	Trace	1.3[a]	4.2[a]	25.9	4.7[a]	14.5[a]	45.7	4.0
20%	Trace	Trace	2.4[b]	6.3[b]	26.5	5.5[a]	11.5[b]	44.7	3.3
40%	Trace	Trace	3.5[c]	8.0[c]	25.7	6.6[b]	9.3[c]	44.0	3.2
	Composition of coconut oil in feed								
Purified coconut oil	15.1	10.0	48.2	14.5	6.2	Trace	1.6	3.8	0.6
Coconut meal fat	8.8	7.6	49.5	17.2	8.4	0.0	1.8	6.1	0.6

[a, b, c] For a single criterion, values on the same vertical column having the same or no superscript letters are not significantly ($P<.05$) different (Duncan, 1955).

Traces of $C14^{=1}$, C15, C17 and $C18^{iso}$ were also found in all samples.

lauric, myristic, and palmitoleic acids. This should be expected since the coconut meal contained 5.8% coconut fat. It is not clear, however, why there was a depression of stearic (C_{18}) acid with no significant decrease in oleic. These changes did not occur when coconut oil was added alone. There was also no significant change in palmitic acid, whereas there was when the oil was added.

Summary

One trial involving 150 quail (*Coturnix c. japonica*) and two trials involving a total of 94 pigs were conducted to study the effect of the use of coconut meal and coconut oil in diets for these animals. The trial with quail was designed to study the effect on rate and efficiency of gain of including 20 or 40% coconut meal with and without added lysine in diets containing two energy sources. Trial 1 with pigs was designed to study the effects of 0, 10, 20 and 40% coconut meal and 0 and 10% coconut oil on pig performance, carcass leanness, physical composition of the ham and fatty acid composition of backfat. The second swine trial was designed to determine if increasing the protein or lysine levels would overcome the depressing effect of 20 or 40% coconut meal when included in corn-soybean meal diets. Pigs fed diets containing 0, 10, 20 and 40% coconut meal gained 0.76, 0.74, 0.65 and 0.46 kg daily and required 2.51, 2.68, 2.75 and 3.27 kg feed/kg gain, respectively. Loineye area and ham weight declined with increasing increments of coconut meal. Increasing protein and lysine levels did not overcome the depression in gain or muscle development due to coconut meal. It can be concluded that some factor other than a lack of adequate level of protein or lysine caused the depressing effect of coconut meal.

Coconut oil and coconut meal additions resulted in relative increases in the lower saturated fatty acids in the backfat. When coconut meal was fed, there was a decrease in stearic acid with little change in oleic acid. This effect was opposite to that of feeding coconut oil.

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