Comparative efficiency of selected phosphates as P-carriers for coconut (*Cocos nucifera* L.)*

H. Hameed Khan, M.P. Sankaranarayanan, O.P. Joshi, M.V. George and K.B. Narayana

Division of Soil Science, Central Plantation Crops Research Institute, Kasaragod-670 124, Kerala, India

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The results of a field experiment conducted for six years on laterite soil showed that single superphosphate, ammonium phosphate, nitrophosphate and rock phosphate had similar effects on the yield of nuts palm^{-1} yr^{-1}. However, when percentage yield increase over pretreatment yield was computed, rock phosphate proved best, followed by ammonium phosphate. Regression analysis revealed an optimum interaction between soil available P and leaf P for rock phosphate. The soil available P increased with the increase in the levels of P applied. Nitrophosphate increased the soil available P to a maximum, followed by ammonium phosphate, single superphosphate and rock phosphate. Fertilizer-P application generally reduced soil pH which was most marked with ammonium phosphate. The treatments showed marginal mobility of P to the subsoil which has been attributed to mechanical movement as a result of cultural operations in the coconut basin. Higher levels of applied P influenced the leaf P values which were not reflected in the yield. Costs of fertilizer indicated that rock phosphate as a P-carrier is cheapest.

Keywords: P-carriers; Coconut; Phosphate fertilizer; *Cocos nucifera* (L.)

Response of coconut to phosphate fertilization has drawn the attention of many coconut researchers (Eden *et al.*, 1963; Pandalai and Krishna Marar, 1964; Barile and Azucena, 1972). The poor response to applied P was mainly attributed to the inherent nature of the soil and low P requirement of the plant system (Sherman, 1971; Manciot *et al.*, 1979). In acid laterite soils the advantage of using a particular carrier of P has been demonstrated with other crops, *viz.* sorghum (McLean and Logan, 1970; Raj Prithivi *et al.*, 1975), rice, sugarcane, finger millet and irrigated pearl millet (Shetty *et al.*, 1973) and potato (Mathen *et al.*, 1977). Loganathan and Nalliah (1977) compared the efficiency of concentrated superphosphate and rock phosphate on coconuts growing in the dry zone of Sri Lanka and suggested that a mixture of the two would be an ideal carrier of P for coconut. However, no information is available so far on the usefulness of different forms of P-carriers for coconut in India.

The results of six years of investigation presented in this Paper analyse the comparative efficiency of four different carriers of P – single superphosphate, ammonium phosphate, nitrophosphate and rock phosphate – in an attempt to find a suitable P-carrier for acidic soils in coconut fertilization programmes.

Materials and methods

A field experiment was laid out in May 1975 on a lateritic soil of gravelly sandy clay loam texture on mature West Coast Tall palms. The soil was acidic (pH 5.2–6.4); soil available P was between 18 and 56 ppm at 0–30 cm depth, with a trace in the subsoil horizons. The experiment was laid out in a randomized block design with three replications comprising five palms per plot. Single superphosphate (0–16–0), ammonium phosphate (16–20–0), nitrophosphate (15–15–15) (Suphala) and powdered rock phosphate (0–32–0) were applied for six years at rates of 0, 160, 320 and 480 g P_2O_5 palm^{-1} yr^{-1} over a basal dressing of 500 g N palm^{-1} as urea and 1200 g K_2O palm^{-1} as muriate of potash after compensating for N and K added through the two P-carriers. Two split dressings were applied, in May and September, and were forked into the soil to a depth of 30 cm after initially broadcasting at a radius of 1.0–1.2 m from the palm.

Soil samples at three depths, 0–30, 30–60 and 60–90 cm, were collected from the basins every year during the month of May and air-dried; sieved samples (2 mm) were analysed for available P (Bray-1 extractant) and pH (1 : 2.5). The fractionation of soil inorganic P was carried out by the procedure of Chang and Jackson (1957) as modified by Peterson and Corey (1966). Leaf samples from the 14th frond (Prevot and Bachy, 1962) were collected from each treatment, washed with deionized water, oven-dried and powdered (0.5 mm) in a Wiley mill before analysis. P (vanadomolybdate) and K (flame photometry) were analysed after digestion in 1 : 2 perchloric : nitric acid mixture (Jackson, 1967).

Results and discussion

The distribution of Bray-1 extractable soil P in the coconut basins varied from 18.0 to 56.0 ppm at 0–30 cm depth, traces to 3.3 ppm at 30–60 cm and traces to 1.3 ppm at 60–90 cm during the pretreatment period (Table 1). As a result of a 6 year fertilizer application, the soil available P increased considerably, regardless of the P-carrier used, and in accordance with the level applied. Of the four P-carriers employed, nitrophosphate was found to

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Table 1 Influence of P-carriers and levels of P on the available P (Bray-1) status in the coconut basins

Carrier of P	Levels ($g\ P_2O_5\ palm^{-1}\ yr^{-1}$)	Available P status (ppm) 1975–76 (pretreatment) 0–30 cm	1975–76 (pretreatment) 30–60 cm	1975–76 (pretreatment) 60–90 cm	1980–81 0–30 cm	1980–81 30–60 cm	1980–81 60–90 cm
Single superphosphate	0	43.4	1.3	0.7	12.9	2.6	1.5
	160	50.0	0.7	tr^a	54.9	9.8	1.4
	320	34.7	3.3	1.3	132.8	3.7	3.1
	480	27.3	2.7	tr	211.9	8.1	2.3
Ammonium phosphate	0	46.7	tr	tr	17.5	2.6	1.0
	160	46.0	tr	tr	59.5	2.9	1.6
	320	36.0	tr	tr	152.7	3.5	3.1
	480	36.0	tr	tr	218.0	10.6	4.4
Nitrophosphate	0	37.3	3.3	tr	20.6	2.6	3.2
	160	18.0	2.7	0.7	75.4	4.3	1.8
	320	29.3	tr	tr	148.1	5.8	1.3
	480	26.0	tr	tr	285.8	6.9	1.8
Rock phosphate	0	56.0	tr	tr	19.6	2.5	1.4
	160	50.7	tr	tr	71.5	4.9	1.0
	320	40.7	tr	tr	91.1	3.5	2.7
	480	39.3	tr	tr	142.6	5.1	4.4

^{a} tr, Traces

increase available P in the 0–30 cm depth of profile at the higher levels of application to a greater degree than ammonium phosphate, single superphosphate and rock phosphate. Where lower levels of P per palm were applied (160 g $palm^{-1}$) significantly higher quantities of P remained in the 0–30 cm depth with nitrophosphate and rock phosphate. A slight mobility of P to lower depths was also observed in the laterite soil. Hameed Khan *et al.* (1983) observed considerable movement of P to lower depths in a red sandy loam soil in the coconut basins. P has been reported to move only by slow diffusion in the soil (Barber, 1962). Because of the gravelly nature of the subsoil horizons, the observed slight mobility of P may be expected, if only from mechanical movement of P-rich particles, reaction products or of unreacted P fertilizer, along with percolation water associated with the heavy rainfall of the area (3500 mm yr^{-1}). Nevertheless, regardless of the P-carrier, the mobility of P increased with the increase in the level of P application (Table 1).

The basins of the palms receiving no P also showed a slight mobility of native P to the subsoil after six years of experimentation, an observation which supports the view that mechanical movement of P is a result of cultural practices associated with fertilizer application in the existing situation. In no-P basins, reduction of soil-available P in the surface layer (0–30 cm) to the extent of 17–37 ppm was recorded in a period of over six years. Kushwah *et al.* (1973) demonstrated that $> 80\%$ of coconut roots are seen below 30 cm depth, and as P moves to the root mainly by diffusion (Barber, *ibid.*) it may be suggested that a more rational approach to P fertilization of tree crops such as coconut would be by way of deeper placement for better utilization. The reduction in soil P content observed over the experimental period in control plots might be the result of P transformation and uptake by the crop.

In general, the soil pH in the coconut basins was found to decrease from an initial value of 5.2–6.4 to 4.2–4.4 over the six years as a result of fertilizer application. A significant reduction in soil pH was observed in the basins receiving ammonium phosphate as one of the P-carriers (Table 2). Although ammonium phosphate is a soluble P-carrier, continued use of it in a fertilizer programme for a perennial crop such as coconut should be avoided as it may lead to extreme acidic conditions in the coconut basins.

P fractionation studies revealed that the forms of P in the soil were related to the P-carrier (Table 3). Application of single superphosphate, nitrophosphate and ammonium phosphate did not alter the occluded and Ca–P fractions, whereas considerable increase in reductant soluble-P, Fe–P and Al–P were seen. A similar trend was apparent with the application of rock phosphate, except that there was an appreciable increase in the Ca–P fraction. Loganathan and Nalliah (1977) also indicated that any P fertilizer applied is not likely to be transformed into an occluded form. A considerable enrichment of the Ca–P fraction indicated that most of the applied rock phosphate remained in the soil as apatite (Humphreys and Pritchett, 1971), as was also observed by Loganathan and Nalliah (*ibid.*). The coconut palm, with its very extensive feeding zone and heavy mycorrhizal infection (Ramesh, Joshi and Hameed Khan, 1983, unpublished work, Central Plantation Crops Research Institute, Kasaragod) is not expected to be selective towards any specific P fraction to meet its P requirement. A P-carrier enriching all the P fractions may, therefore, be ideal for the crop. The results obtained reveal that rock

Table 2 Effect of six years' continuous application of P fertilizers on soil pH

Fertilizer	Soil depth (cm) 0–30	30–60	60–90
Without P fertilizer	5.4	5.0	4.6
Single superphosphate	4.7	4.5	4.5
Ammonium phosphate	4.6	4.2	4.4
Nitrophosphate	4.8	4.6	4.7
Rock phosphate	4.8	4.6	4.7
LSD, $P = 0.05$	0.17	0.17	–

Table 3 Distribution of P fractions (ppm) as influenced by P-carrier and levels of P

Carrier of P	Levels (g P_2O_5 palm^{-1} yr^{-1})	0–30 cm Saloid P	Al–P	Fe–P	Redn sol.P	Occl. P	Ca–P	30–60 cm Saloid P	Al–P	Fe–P	Redn sol.P	Occl. P	Ca–P
Single superphosphate	0	1.3	79.9	135.2	568.5	25.6	27.3	0.1	7.9	34.8	409.1	22.7	9.4
	160	1.6	156.6	181.1	624.0	37.6	42.9	0.2	25.9	78.3	506.1	27.5	21.1
	320	2.8	117.9	204.0	637.1	32.3	44.2	0.2	18.3	76.7	416.0	30.4	13.7
	480	5.1	271.2	231.7	603.2	33.9	49.7	0.4	46.8	94.9	395.2	30.1	25.4
Nitrophosphate	0	0.5	54.2	127.3	575.5	30.7	28.6	tr[a]	7.0	33.2	312.0	22.0	10.1
	160	1.6	89.4	163.7	540.8	28.2	29.6	0.1	20.2	37.2	409.1	25.3	8.1
	320	2.9	151.8	202.4	589.3	30.7	45.5	0.2	27.2	90.9	443.7	27.2	20.1
	480	8.7	328.9	264.9	651.7	40.2	62.4	0.4	17.7	98.8	464.5	29.4	17.8
Ammonium phosphate	0	0.5	84.6	163.4	748.9	31.6	50.1	0.1	10.8	46.9	339.7	29.1	16.5
	160	1.7	172.4	197.5	679.5	37.6	54.0	0.2	24.7	70.4	429.8	33.5	16.9
	320	5.2	260.8	253.1	693.3	36.7	59.5	0.6	34.2	86.2	443.7	37.8	20.8
	480	7.0	364.5	458.6	658.7	36.4	45.8	1.1	29.1	88.5	298.1	24.5	13.0
Rock phosphate	0	1.8	99.6	140.7	492.3	37.6	39.7	0.2	11.1	49.0	499.2	30.1	13.0
	160	5.2	132.0	177.9	686.4	38.4	160.9	0.5	19.6	78.3	582.4	28.2	21.5
	320	5.1	152.6	194.7	561.6	34.2	259.8	0.3	31.3	65.6	367.5	23.1	49.4
	480	11.2	253.8	229.3	721.1	48.4	431.7	0.2	8.9	53.0	381.3	24.7	57.2

[a] tr, Traces

phosphate is such a carrier and may be best for fertilizing coconut.

The pretreatment levels of N (1.29–1.40%), P (0.087–0.100%), K (0.39–0.57%), Ca (0.32–0.49%) and Mg (0.23–0.48%) in the diagnostic leaf indicated that these elements in all the palms were below critical levels (Fremond, 1966). A substantial increase over pretreatment levels was recorded as a result of fertilizer application with different carriers of P and blanket application for N and K; the increase

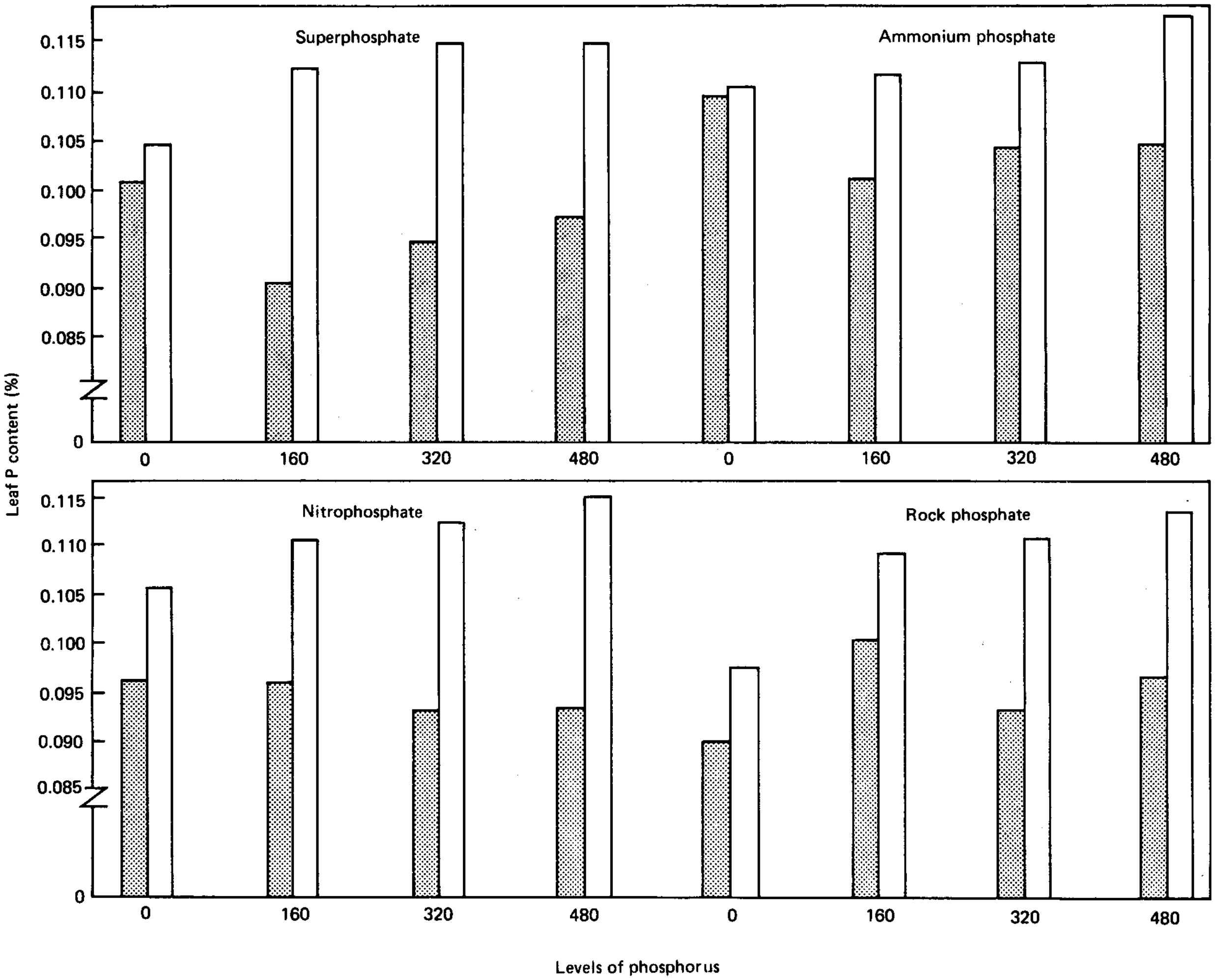

Fig. 1 Influence of P-carriers and levels on the foliar P (14th leaf) of coconut. ▨, Pretreatment levels; □, post-treatment levels

Table 4 Coefficient of determination (R^2) for the simple and multiple regressions of leaf-P content (Y) on soil-P at three soil depths (x)[a]

Model	Depth (cm)	Single superphosphate	Nitrophosphate	Ammonium phosphate	Rock phosphate
(A) $Y = a + bx$	0–30	0.18	0.37	0.22	0.82^b
	30–60	0.19	0.23	0.11	0.54^b
	60–90	0.13	0.24	0.10	NS
(B) $Y = a + b_1x_1 + b_2x_2 + b_3x_3$	–	0.28	0.64^c	0.29	0.84^b

[a] x and x_1, x_2 and x_3 are the soil-available P levels at various depths with respect to models A and B, respectively; NS, not significant

[b] $P = 0.01$

[c] $P = 0.05$

was more conspicuous for N and K, even in the first year, than for P following fertilizer application. Fertilizer application with different carriers and levels of P for five years could increase the foliar P levels gradually, but neither the carriers nor the levels of P could bring leaf P contents near or above the critical levels. This suggests that building up of P in the coconut system could be effected only over a period of time. The four sources tried were equally effective in increasing the P levels (Fig. 1). The plant P level was found to be influenced by levels of P applied and consequent increase in soil available P. The increase in leaf P was found to be dependent on the initial leaf P status. The levels of 160 and 320 g P_2O_5 palm^{-1} yr^{-1} were not as effective as 480 g P_2O_5 in increasing the leaf P levels, possibly because a rich P environment (at 480 g P_2O_5 level) aids greater diffusion of P to the roots.

The linear regression of leaf P on soil available P indicated that for rock phosphate the regression coefficients for soil values of 0–30 cm and 30–60 cm depths were significant (Table 4). For nitrophosphate the correlation was significant only at the 0–30 cm depth, whereas no such relationship was observed with other P-carriers. The significance of available P at both depths when rock phosphate was used as a P-carrier indicated optimum interaction of available P on leaf P.

A significant relationship was obtained between soil-available P and leaf P, but leaf P values were not found to be related to yield, even though the leaf P values increased with the increase in levels of P applied.

Yield data (Table 5) did not reveal any significant differences due to P-carriers or levels of P applied over the years, but an increase over the pretreatment yield was obtained. When the percentage increases in yield over pretreatment yields are compared, ammonium phosphate and rock phosphate at higher levels (320 and 480 g palm^{-1} yr^{-1}) showed appreciable increases, indicating the superiority of these carriers as P fertilizers for coconut. The odd behaviour of yield during the fifth year of fertilizer application may be ascribable to high statistical variation obtained. The increase in yields, even in control plots where no P was applied, suggests that supplemental P may not be of great importance in the nutrition of adult coconut palms when a particular available-P status of the soil is reached.

The cost of fertilizer applied per palm was least (Rs 5.81) with rock phosphate, followed by superphosphate (Rs 6.10), ammonium phosphate (Rs 6.51) and nitrophosphate (Rs 6.55).

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Table 5 Influence of P-carriers and P levels on the yield of coconut palms over six years

P-carrier	Levels (g P_2O_5 palm^{-1} yr^{-1}	Pre-treatment yield (nuts)	Yield of nuts					% Increase in yield after			
			1st yr	2nd yr	3rd yr	4th yr	5th yr	Two yrs	Three yrs	Four yrs	Five yrs
Single superphosphate	0	31.6	43.3	47.1	41.3	37.6	30.3	42.9	38.9	34.0	26.3
	160	34.6	40.1	48.1	62.9	40.7	40.0	27.4	45.4	38.4	33.8
	320	28.5	34.3	46.2	46.9	34.7	30.0	47.1	49.8	42.4	34.9
	480	35.2	36.3	48.2	50.6	41.0	53.3	20.0	27.9	25.2	30.4
Ammonium phosphate	0	32.0	37.7	45.0	50.5	40.5	28.7	29.3	38.9	35.8	26.6
	160	32.9	34.5	36.1	49.7	32.8	23.7	7.4	22.3	16.0	7.1
	320	26.2	39.9	44.9	59.9	37.1	32.7	62.0	84.3	75.6	16.3
	480	21.8	39.6	42.1	52.9	34.1	32.0	87.1	105.4	93.1	18.8
Nitrophosphate	0	28.0	32.4	30.5	48.7	36.5	30.0	12.3	32.9	32.2	27.1
	160	30.9	36.5	33.7	50.1	37.5	31.0	13.6	40.8	34.2	28.0
	320	26.4	38.7	44.1	49.7	46.5	34.7	56.8	67.3	31.6	15.9
	480	30.7	37.3	37.7	57.9	35.5	30.0	22.3	44.9	62.3	27.2
Rock phosphate	0	35.5	48.2	45.1	58.8	40.3	36.3	37.3	42.7	35.4	31.4
	160	36.0	36.6	44.3	37.7	36.0	25.0	12.4	10.1	24.6	5.0
	320	25.0	36.3	46.5	60.3	42.9	35.7	65.6	90.8	86.0	77.1
	480	23.6	40.3	51.4	59.5	48.6	46.3	94.4	113.7	111.9	108.9
Mean	–	30.7	38.3	43.2	52.9	38.9	34.1	–	–	–	–
SE/plot	–	7.8	10.7	10.7	14.0	9.7	15.2	–	–	–	–
CV%	–	23.6	27.8	24.4	26.6	25.0	44.8	–	–	–	–

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Dried coffee pulp (DCP) as an ingredient in the diets of growing pigs

Daniel B. Okai, Michael L.K. Bonsi and Robert A. Easter

Department of Animal Science, UST, Kumasi, Ghana, and Department of Animal Science, University of Illinois, Urbana, Illinois 61801 USA

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A total of 40 Large White growing pigs were fed diets containing either 0, 5 10, 15 or 20% dried coffee pulp. Each treatment had eight pigs in two replicate lots of four. After a 12 week feeding trial, during which both feed and water were available *ad libitum*, half of the pigs (males) on each treatment were slaughtered. Average daily feed intake and weight gain, feed conversion efficiency and the various carcass traits measured were not significantly influenced by the inclusion of up to 20% DCP in the diet. It was concluded that up to 20% DCP could be fed to growing pigs.

Keywords: Coffee pulp; Growing pigs; Diet; Food value

Dried coffee pulp (DCP) is obtained as a by-product during the wet- or dry-processing of coffee berries. It is generally considered to be a pollutant, but limited amounts are used for cottage soap manufacture and as fertilizer in coffee plantations in Ghana and elsewhere. According to Bressani *et al.* (1972) it contains 11.2% crude protein, 21% crude fibre, 8.3% ash and 2.5% ether extract; it has a better amino-acid pattern than most cereal proteins and the lysine content is similar to the level found in soya bean meal. Most feeding trials involving the use of DCP were done in Central America, and the results obtained have been summarized by Braham and Bressani (1979). However, only a few of these experiments were carried out with pigs (Jarquin *et al.*, 1974; Jarquin and Bressani, 1976, 1977; Jarquin *et al.*, 1977). Jarquin (1979) concluded that the limited research data available would tend to suggest that DCP levels up to 16% of the diet could be fed to pigs without deleterious effects on performance.

The objective of this experiment was to provide more information on the feeding value of DCP for swine by including levels of DCP varying from 0 to 20% in the diets of growing swine.

Materials and methods

Forty Large White growing pigs were allotted, in a completely randomized design, to five dietary treatments on the basis of sex and weight such that there were four entire males and four females on each dietary treatment. There were two replications (two males and two females) of each treatment and individual replicates were housed in 3.5 × 3.2 m concrete-floored pens with concrete feed and water troughs (1.8 × 0.3 × 0.3 m) in a well-ventilated swine barn.

The compositions of the five diets fed during the experiment are shown in Table 1. Diets were balanced for crude protein content and fresh feed was mixed every two weeks. The varying levels of DCP constituted 0 (D_0), 5 (D_1), 10 (D_2), 15 (D_3) and 20% (D_4) of the diets as a direct replacement for corresponding quantities of the dried brewers' spent grains in the control (D_0) diet. Both feed and water were made available to the pigs *ad libitum* during the 12 week feeding trial.

Weekly feed intake and liveweight changes were recorded; from these, average daily feed intake, weight gains and feed conversion efficiency (feed :

Table 1 Ingredient and percentage composition of diets

	Diets				
Ingredients	D_0	D_1	D_2	D_3	D_4
Maize	56	55	52	50	49
Dried brewers' spent grains	25	20	15	10	5
Dried coffee pulp	–	5	10	15	20
Fish meal	10	11	12	13	14
Copra cake	7	7	9	10	10
Dicalcium phosphate	1	1	1	1	1
Common salt	0.5	0.5	0.5	0.5	0.5
Vitamin-trace mineral premix	0.5	0.5	0.5	0.5	0.5
Analysed composition (%)					
Crude protein	18.2	18.0	17.9	17.5	17.9
Crude fibre	7.2	7.4	7.6	8.2	8.6
Ether extract	3.2	2.9	1.2	1.2	1.2
Ash	7.4	6.1	7.0	7.6	8.2

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