Nutritional value, for pigs and rats, of sunflower oilcake meal processed to contain different concentrations of protein

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Different amounts of hull were removed from sunflower oilcake to obtain oilcake with a protein content of 40% (SFOC 40), 42% (SFOC 42), 44% (SFOC 44) and 46% (SFOC 46), respectively. The increase in crude protein content from 40% to 46% resulted in a concomitant increase in the concentration of amino acids. Lysine increased from 1.21% to 1.42% and the S-containing amino acids from 1.53% to 1.89%. The concentrations of these amino acids expressed as g/100 g protein remained constant. In contrast, crude fibre decreased from 19.1% to 14.0%. The relative nutritive value (RNV), in rats, of SFOC 40 (50%) did not differ significantly ($P > 0.05$) from that of SFOC 46 (47%). The addition of synthetic lysine significantly ($P < 0.05$) improved RNV (69% for SFOC 40 and 67% for SFOC 46). True protein digestibility was not improved ($P > 0.05$) by removing more hull (84% for SFOC 40 and 85% for SFOC 46) or by the addition of synthetic lysine (84% to 86% for SFOC 40 and 85% to 87% for SFOC 46). No significant differences ($P > 0.05$) could be found in mean growth rate (0.77 kg/day and 0.80 kg/day) and feed conversion ratio (3.1 kg/kg and 3.0 kg/kg) between pigs that received diets formulated on an isonutrient basis using sunflower oilcake meals containing different concentrations of protein (SFOC 40 and 46, respectively). The bioavailable energy for pigs (DE) and poultry (TME and TME_n) did not differ significantly ($P > 0.05$) between SFOC 40 and SFOC 44.

Verskillende hoeveelhede dop is uit sonneblomoliekoekmeel verwyder om oliekoekmele met 'n proteïeninhoud van 40% (SBOK 40), 42% (SBOK 42), 44% (SBOK 44) en 46% (SBOK 46), onderskeidelik, te verkry. Die toename in ru-proteïeninhoud van 40% tot 46% het 'n gelyktydige toename in die konsentrasie van aminosure tot gevolg gehad. Lisien het toegeneem van 1.21% tot 1.42% en S-bevattende aminosure van 1.53% tot 1.89%. Die konsentrasies van hierdie aminosure, uitgedruk as g/100 g proteïen, het egter konstant gebly. In teenstelling hiermee het die ru-vesel afgeneem vanaf 19.1% tot 14.0%. Die relatiewe voedingswaarde (RNV) wat met rotte bepaal is van SBOK 40 (50%) het nie betekenisvol ($P > 0.05$) van dié van SBOK 46 (47%) verskil nie. Die byvoeging van sintetiese lisien het die RNV (69% vir SBOK 40 en 67% vir SBOK 46) betekenisvol ($P < 0.05$) verbeter. Ware proteïenverteerbaarheid is nie verbeter ($P > 0.05$) deur meer dop te verwyder (84% vir SBOK 40 en 85% vir SBOK 46) of deur die byvoeging van sintetiese lisien nie (84% tot 86% vir SBOK 40 en 85% tot 87% vir SBOK 46). Geen betekenisvolle verskil ($P > 0.05$) in gemiddelde groeitempo (0.77 kg/dag en 0.80 kg/dag) en voeromsettingsverhouding (3.1 kg/kg en 3.0 kg/kg) is tussen varke, wat diëte ontvang het wat op 'n isonutriëntbasis geformuleer is en sonneblomoliekoekmele wat verskillende proteïenkonsentrasies bevat het, verkry nie (SBOK 40 en SBOK 46, respektiewelik). Die biobeskikbare energie vir varke (VE) en pluimvee (TME en TME_n) het nie betekenisvol ($P > 0.05$) tussen SBOK 40 en SBOK 44 verskil nie.

Keywords: Digestible energy, pigs, poultry, protein content, rats, relative nutritive value, sunflower oilcake meal, true metabolizable energy, true protein digestibility.

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Introduction

Sunflower oilcake meal is the plant protein source most commonly used in commercial diets in South Africa. About 172 000 tons (1987 to 1991) of sunflower oilcake meal are produced annually (Dept. Agriculture, 1991). Approximately 60% of the local production is used to feed monogastric animals, emphasising the importance of sunflower oilcake meal as a protein source (Mordant, 1981).

In the production of sunflower oilcake meal, it is possible to control the amount of hull that is removed before the oil is expressed. By removing a greater portion of hull, the nutrient density of the meal is increased while the crude fibre content is decreased. However, when too much hull is removed, a greater portion of kernel is lost which results in a lower oil recovery and loss of income. The question is whether the loss of this portion of kernel has an influence on the quality or composition of the remaining protein.

This study was therefore conducted to establish to what extent the extra removal of hull, which results in higher protein concentrations but a concomitant loss of a portion of the kernel, will affect the nutritional value of the resulting oilcake meals for rats and pigs. These results will be used to decide whether it pays to add value to the oilcake meals by removing more hull.

Materials and Methods

Three oilcake meals, obtained from a commercial mill, contained 40% (SFOC 40), 44% (SFOC 44) and 46% (SFOC 46) protein, respectively. The SFOC 40 and SFOC 44 meals were blended to obtain a 42% meal (SFOC 42).

Chemical composition

The meals were analysed for dry matter, ash, ether extract, crude fibre, crude protein, amino acid composition, phosphorus and calcium according to standard methods previously reported by Nell *et al.* (1992). Total sugars (reducing and non-reducing) and starch were determined according to AOAC (1984). The Fibertec system (Robertson & Van Soest, 1981) was used to determine neutral detergent fibre.

Protein contents of the SFOC meals were used as independent, and g amino acid/100 g protein as dependent variables in a regression analysis (Snedecor & Cochran, 1980). A significant deviation from zero, of the slope of the regression line, would indicate a change in the amino acid composition, resulting from an increase in the protein content of the SFOC meal.

Protein quality and digestibility using a rat assay

The amino acid composition of sunflower kernels differs from that of sunflower hull (Perez *et al.*, 1986). It may also be that the kernel consists of stratified proteins which will be lost when a specific portion of the kernel is lost with the hull. Sunflower oilcake that differs in the amount of hull may therefore differ in protein quality.

The protein quality was determined using a multi-point, slope ratio assay as developed by Hegsted *et al.* (1968) and adapted by Nell *et al.* (1992). SFOC 40 and SFOC 46 were used as experimental protein sources, while lactalbumin was used as reference protein. Three gram synthetic lysine per 100 g of protein was added to SFOC 40 and SFOC 46 to simulate two sunflower proteins that meet the lysine requirement for growing rats (4.5 g/100 g protein; NRC, 1978). The lysine was added in order to determine the effect of the different SFOC meals on protein quality when lysine was no longer the first limiting amino acid. Sixty-two male Wistar rats were divided into 17 groups of equal average live mass at 27 days of age and fasted for 24 h, after which the initial slaughter group (n = 9) was asphyxiated and the protein content of each rat was determined according to the method described by Nell *et al.* (1992). One group (n = 8) received a protein-free diet, whilst the remaining 15 groups of three rats each were randomly allocated to the other treatments shown in Table 1.

Nitrogen intake was used as the independent variable and nitrogen accretion as the dependent variable in a regression analysis for each protein source. Protein true digestibility (PTD) was estimated by the method described by Donnelly *et al.* (1983) and adapted by Nell *et al.* (1992). Analyses of covariance were performed on the relative nutritive value (RNV) and PTD data using nitrogen intake as covariate (Snedecor & Cochran, 1980).

Table 2 Composition of the experimental diets used in the pig growth trial on an air-dry basis (%)

		Sunflower oilcake diet			
	Control	40	42	44	46
Component					
Maize meal	73.9	69.9	68.7	67.7	66.8
Wheaten bran	2.6	2.9	6.5	9.5	11.7
SFOC 40	–	23.0	–	–	–
SFOC 42	–	–	20.7	–	–
SFOC 44	–	–	–	18.8	–
SFOC 46	–	–	–	–	17.4
Soya meal	19.0	–	–	–	–
Synthetic lysine	0.33	0.67	0.67	0.67	0.67
Mono-Ca-P	1.1	0.9	0.9	0.8	0.8
Limestone	2.1	1.5	1.5	1.5	1.6
Fine salt	1.0	1.0	1.0	1.0	1.0
Minerals & vitamins	0.02	0.02	0.02	0.02	0.02
Composition[1]					
Crude protein (%)	16.0	16.0	16.0	16.0	16.0
Crude fibre (%)	3.5	6.7	6.2	5.9	5.6
Digestible energy (MJ/kg)	13.2	13.2	13.2	13.2	13.2
Lysine (%)	1.01	1.01	1.01	1.01	1.01

[1] Calculated % air dry.

Table 1 Composition, on an air-dry basis (%), of the experimental diets used for the relative nutritive value and true protein digestibility assays with rats

Component	Control	SFOC 40			SFOC 46			SFOC 40 + Lysine			SFOC 46 + Lysine			Lactalbumin		
Crude protein	0	3	6	9	3	6	9	3	6	9	3	6	9	3	6	9
Maize starch	90.0	82.5	75.1	67.6	83.5	77.1	70.6	82.6	75.2	67.8	83.6	77.2	70.8	86.3	82.5	78.7
Sunflower oil	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Min. & vit. premix[1]	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Lysine	–	–	–	–	–	–	–	0.09	0.17	0.25	0.09	0.17	0.25	–	–	–
Lactalbumin	–	–	–	–	–	–	–	–	–	–	–	–	–	3.7	7.5	11.3
SFOC 40	–	7.5	14.9	22.4	–	–	–	7.3	14.6	22.0	–	–	–	–	–	–
SFOC 46	–	–	–	–	6.5	12.9	19.4	–	–	–	6.3	12.6	19.0	–	–	–

[1] Mineral & vitamin premix, supplied per kilogram feed: Vitamin A, 2.0 IU; Vitamin D, 1000 IU; Vitamin E, 35 mg; Vitamin K, 50 µg; Thiamin hydrochloride, 1.25 mg; Riboflavin, 2.5 mg; Vitamin B12, 50g; Calcium pantothenate, 8 mg; Niacin, 15 mg; Choline chloride, 750 mg; Cu, 5 mg; Mn, 50 mg; Zn, 12 mg; I, 0.15 mg; Fe, 35 mg; Se, 0.04 mg; Mg, 0.4 g; P, 4.0 g; K, 1.8 g; Na, 0.5 g; Ca, 5.0 g.

Pig growth trial

Five isonutrient diets were formulated (Table 2). The diets were isonutrious regarding crude protein, lysine and digestible energy. All the diets complied with the standards of a commercial 16% pig grower diet. The protein source for each diet was one of the four sunflower oilcakes with soyabean oilcake used in the control diet. The diets were randomly allocated to five groups of 11 pigs, each group consisting of 7 boars (5 Large White and 2 Landrace) and 4 gilts (3 Large White and 1 Landrace). The pigs were fed *ad libitum* from approximately 25 to 90 kg live mass. The pigs were individually housed in flat deck cages, 1.6 × 1 m, fitted with a self-feeder and an automatic water nipple. Temperatures were controlled to the extent that minimum temperatures did not drop below 20 °C and maximum temperatures seldom rose above 30 °C. Values for body mass and feed intake were determined every fourth day. Feed and water were not withheld before mass determinations. Mean growth rates and feed conversion ratios for the growth interval 30 to 90 kg live mass were calculated using the allometric autoregressive growth model (Siebrits, 1986). Analyses of variance were performed on the data using the Harvey least-square means statistical package (Harvey, 1988).

Bioavailable energy (BE)

Digestible energy (DE) for pigs was determined using the mobile nylon bag technique (MNBT) described by Sauer & Ozimek (1985) and adapted by Brand *et al.* (1989).

The method of Sibbald (1976), as adapted by McNab & Fisher (1984), was used to determine true metabolizable energy (TME) content of the SFOC. Corrections, as proposed by Wolynetz & Sibbald (1984), for nitrogen retention were made to determine TME_n. The feeding method described by Du Preez *et al.* (1984) was also used to determine TME (DSQ) and TME_n (DSQ).

BE values were determined on SFOC 44 as the high protein source since the original batch of SFOC 46 was not large enough to carry out all the determinations. The significance of the differences in means of the BE values was tested using the Student's *t* test (Snedecor & Cochran, 1980).

Table 3 Chemical composition of the experimental sunflower oilcake meals on an air-dry basis (%)

Component	Sunflower oilcake meal 40	42	44	46
Crude protein (N × 6.25)	40.1	42.3	44.4	46.4
Dry matter	90.1	90.3	90.6	90.4
Ash	8.8	8.6	8.4	8.5
Ether extract	2.4	2.2	2.0	2.4
Crude fibre	19.1	17.3	15.6	14.0
Neutral detergent fibre	28.0	25.5	23.4	21.5
Sugars	0.71	0.68	0.69	0.73
Calcium	0.34	0.35	0.33	0.34
Phosphorus	1.09	0.89	0.95	1.05
Amino acids:				
Lysine	1.21	1.24	1.34	1.42
Methionine	0.63	0.73	0.76	0.83
Cystine	0.90	0.97	1.00	1.06
Threonine	1.15	1.23	1.31	1.40
Isoleucine	1.27	1.37	1.48	1.54
Leucine	2.14	2.36	2.50	2.58
Phenylalanine	1.60	1.61	1.71	1.80
Histidine	0.73	0.79	0.90	0.95
Arginine	2.62	2.79	2.94	3.07
Valine	1.40	1.51	1.60	1.72

Results and Discussion

Chemical composition

The chemical composition of the sunflower oilcake meals used in this study is presented in Table 3.

Crude protein content increased from 40% to 46%. The amino acid concentrations in the oilcakes increased concomitantly with the removal of more hull, i.e. with the increase in protein. For example, lysine increased from 1.21% to 1.42% and the S-containing amino acids from 1.53% to 1.89%. The concentrations of these amino acids, expressed as g/100 g protein remained constant (Table 4). As expected, crude fibre content decreased from 19.1% to 14.0%. The fat content of SFOC 40 and SFOC 46 did not differ, suggesting that the efficiency of fat extraction was not affected by the amount of hull that had been removed prior to fat extraction.

Protein quality and digestibility measured with rats

The RNV of the experimental sunflower oilcake meals (Table 5) did not differ significantly from each other ($P > 0.05$). It can therefore be concluded that the composition and quality of the protein that was lost during dehulling did not affect the quality of the remaining protein. The values of 0.43 (SFOC 40) and 0.41 (SFOC 46) were lower than those normally found for protein sources such as cottonseed meal (0.61), fish-meal (0.60) and fullfat soyabean meal (0.65) (Hegsted *et al.*, 1968). Addition of synthetic lysine increased RNV values significantly ($P < 0.01$) to 0.60 (SFOC 40) and

Table 4 Amino acid composition of the experimental sunflower oilcake meals, expressed as g amino acid/100 g protein, and the slopes of the regression lines of protein content vs. amino acid content (g/100 g protein)

Amino acid	Sunflower oilcake meal 40	42	44	46	Slope[1] ± *SE*
Lysine	3.34	3.24	3.33	3.38	0.01 ± 0.01
Methionine	1.75	1.91	1.89	1.98	0.03 ± 0.02
Cystine	2.49	2.53	2.48	2.52	0.00 ± 0.01
Threonine	3.19	3.22	3.27	3.34	0.02 ± 0.01
Isoleucine	3.52	3.59	3.67	3.66	0.02 ± 0.01
Leucine	5.94	6.17	6.22	6.14	0.03 ± 0.04
Phenylalanine	4.44	4.21	4.26	4.29	−0.02 ± 0.02
Histidine	2.02	2.06	2.23	2.26	0.03 ± 0.02
Arginine	7.26	7.30	7.32	7.33	0.01 ± 0.02
Valine	3.87	3.95	3.99	4.09	0.03 ± 0.02

[1] Not significantly ($P > 0.05$) different from zero for any one of the amino acids.

Table 5 Relative nutritive value, measured with rats, of the experimental sunflower oilcake meals with body protein accretion as response to protein intake (common intercept = −0.193)

Protein source	Slope ± *SE*[1]	RNV ± *SE*
Lactalbumin	0.86[a] ± 0.012	1.00
SFOC 40	0.43[b] ± 0.017	0.50 ± 0.027
SFOC 46	0.41[b] ± 0.010	0.47 ± 0.018
SFOC 40 + Lysine	0.60[c] ± 0.013	0.69 ± 0.026
SFOC 46 + Lysine	0.57[c] ± 0.011	0.67 ± 0.023

[a–c] Slopes with different superscripts differ significantly ($P < 0.05$).
[1] Standard error of the estimate.

Table 6 Protein true digestibility (PTD), measured with rats, of the experimental diets containing lactalbumin and sunflower oilcake meal

Protein source	Slope ± *SE*[1]	PTD ± *SE*
Lactalbumin	0.04[a] ± 0.010	96 ± 0.5%
SFOC 40	0.16[b] ± 0.013	84 ± 1.4%
SFOC 40 + Lysine	0.14[b] ± 0.012	86 ± 1.3%
SFOC 46	0.15[b] ± 0.012	85 ± 1.3%
SFOC 46 + Lysine	0.13[b] ± 0.013	87 ± 1.4%

[a,b] Slopes with different superscripts differ significantly ($P \leq 0.05$).
[1] Standard error of the estimate.

Table 7 Mean growth rates and feed conversion ratios for pigs, calculated for the growth interval 30–90 kg live mass (n = 11 per treament). No significant ($P > 0.05$) differences were found between diets

Protein source	Growth rate ± *SE*[1] (kg/day)	FCR[2] ± *SE*[1] (kg/kg)
SFOC 40	0.77 ± 0.02	3.1 ± 0.1
SFOC 42	0.75 ± 0.02	3.0 ± 0.1
SFOC 44	0.79 ± 0.02	3.0 ± 0.1
SFOC 46	0.80 ± 0.02	3.0 ± 0.1
Soya oilcake	0.77 ± 0.02	2.7 ± 0.1

[1] *SE* = Standard error.
[2] Feed conversion ratio.

0.57 (SFOC 46), thus indicating that lysine was the first limiting amino acid in SFOC protein.

The PTD values, together with the slopes of the equations used to calculate PTD, are listed in Table 6.

The PTD values for the diets that contained the experimental sunflower oilcake meals did not differ significantly between treatments ($P > 0.05$). In a digestion trial with growing pigs, Green & Kiener (1989) found that the true digestibility of nitrogen in sunflower meal with a crude protein content of 36% was 79%, which did not differ significantly ($P > 0.05$) from that of sunflower meal with a crude protein content of 31% (80%). The addition of synthetic lysine to the diets caused a small, non-significant increase in PTD ($P > 0.05$).

Pig growth trial

No significant ($P > 0.05$) differences were found in mean growth rates and feed conversion ratios between pigs fed the different experimental diets (Table 7). As a result of the isonutrious diets that were formulated, it can be concluded that there were no differences in protein quality between the experimental SFOC meals. Thus, the removal of a greater portion of hull in the production process did not affect the protein quality of the sunflower meal in diets for growing pigs.

Bioavailable energy

No significant differences ($P > 0.05$) in BE (pigs and poultry) were found between SFOC 40 and SFOC 44 (Table 8). Perez *et al.* (1986) found that the DE values (pigs) of sunflower oilmeals were highly correlated ($r = -0.96$) with their cell wall contents. In the present study, the crude fibre content of the two meals differed by only 3.5%, while a range of 6% to 28% crude fibre was used by Perez *et al.* (1986). The absence of a significant difference in BE in this study may be ascribed to the small difference in the crude fibre content and to the insensitivity of the methods used to determine BE, owing to large variation.

The equation derived by Kemm (1974) was used to calculate the ME value for pigs from the determined DE values:

$$ME = (0.891\ DE) - (0.025\ CP) + 1.429$$

The ME values for pigs were calculated to be 11.08 and 11.06 for SFOC 40 and SFOC 44, respectively. These ME values were noticeably higher than the ME values determined with

Table 8 Bioavailable energy of the experimental sunflower oilcake meals, for pigs and poultry (MJ/kg air dry)

Measurement[1]	Animals	Method	SFOC 40	SFOC 44
TME	Cockerels	Crop intubation	9.01 ± 0.40 (n = 6)	9.77 ± 0.51 (n = 6)
TME_n	Cockerels	Crop intubation	9.02 ± 0.40 (n = 6)	9.41 ± 0.50 (n = 6)
TME	Cockerels	Dual semi quick	10.78 ± 0.50 (n = 6)	10.06 ± 0.12 (n = 4)
TME_n	Cockerels	Dual semi quick	10.08 ± 0.43 (n = 6)	9.65 ± 0.10 (n = 4)
DE	Pigs	Mobile nylon bag	11.96 ± 0.07 (n = 12)	12.05 ± 0.08 (n = 10)

[1] TME = True metabolizable energy; TME_n = true metabolizable energy with nitrogen retention correction; DE = digestible energy.

No significant differences ($P > 0.05$) between BE values of SFOC 40 and SFOC 44.

poultry. This could be due to the more efficient utilization of dietary fibre by microbes in the hind gut of pigs (Ratcliffe, 1991).

Conclusion

The removal of a greater portion of hull in the production process of sunflower oilcake meal had a marked effect on the chemical composition in terms of a change in the concentration of the nutrients.

There was, however, no significant difference in the protein quality of the experimental oilcakes in terms of relative nutritive value as measured on rats. No significant differences could be found in mean growth rate and feed conversion ratio between pigs which received diets formulated on an iso-nutrient basis, using sunflower oilcake meals that contained different concentrations of protein. Thus, by removing a greater portion of hull in the production process, the protein quality of the sunflower protein was not affected, neither was the difference in bioavailable energy for pigs (DE) and poultry (TME & TME_n) between SFOC 42 and SFOC 44 measurable.

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