Normal and hetero-yellow endosperm grain sorghum as substitute for maize in pig diets

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An experiment was conducted to evaluate a hetero-yellow endosperm sorghum cultivar (G766W) in comparison to a low-tannin (GL) sorghum cultivar as well as maize in a growth trial using pigs. The digestible energy (DE) content of the experimental diets as well as the grain components of these diets was determined by means of the mobile nylon bag technique (MNBT), while the chemical and amino acid compositions were determined by chemical analysis. There were no significant differences between the DE contents of the maize (16,1 MJ/kg DM), GL sorghum (16,6 MJ/kg DM) or G766W sorghum (16,0 MJ/kg DM) or the experimental diets (15,1, 15,2 and 15,3 MJ/kg DM respectively). The CP content (DM basis) of the diets varied between 19,9%, 20,6% and 21,2% for the maize, G766W sorghum and GL sorghum diets respectively, but the diets were almost equal in lysine (0,91, 0,96 and 0,91%) and methionine plus cystine content (0,66, 0,61 and 0,58%). There were no significant differences in average daily gain and feed conversion ratio of pigs fed either maize, GL sorghum or G766W sorghum as the grain component in a balanced diet. It is therefore concluded that, provided that low-tannin grain sorghum of a good quality is used, and provided that the diet is composed to meet the recommended dietary levels, it is possible to optimize pig performance.

'n Eksperiment is uitgevoer om 'n hetrogeelendosperm-graansorghum (G766W) in vergelyking met 'n gewone lae-tannien(GL)-sorghum en mielies in 'n groeistudie met varke te evalueer. Die verteerbare-energie(VE)-inhoud van die eksperimentele diëte sowel as die graankomponente van die diëte is met behulp van die mobiele-kunsveselsakkietegniek (MNBT) bepaal, terwyl die chemiese- en aminosuursamestelling deur chemiese analise bepaal is. Daar is geen betekenisvolle verskille in die VE-inhoud van die mielie- (16,1 MJ/kg DM), GL-sorghum- (16,6 MJ/kg DM) of G766W-sorghummonsters (16,0 MJ/kg DM), of in die VE-inhoud van die eksperimentele diëte (onderskeidelik 15,1, 15,2 en 15,3 MJ/kg DM) gevind nie. Die ruproteïen(RP)-inhoud (DM-basis) van die diëte het gevarieer tussen 19,9%, 20,6% en 21,2% vir die mielies, G766W-sorghum en GL-sorghum onderskeidelik, alhoewel die diëte byna gelyk in lisien- (0,91; 0,96 en 0,91%) en metionien-plus-sisteïeninhoud (0,66; 0,61 en 0,58%) was. Geen betekenisvolle verskille in gemiddelde daaglikse toename en voeromsettingsdoeltreffendheid van varke is tussen die diëte gevind nie. Indien lae-tanniengraansorghum van goeie kwaliteit dus gebruik word en die dieet volgens aanbevole vereistes saamgestel word, behoort geen probleme ondervind te word om optimum produksie te verkry nie.

Keywords: Grain sorghum, maize, mobile nylon bag technique, pigs.

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Grain sorghum and maize are the most important grains used to feed South African pigs. Several researcher found that more sorghum than maize is required per unit of gain and that the feed efficiency of sorghum averages 95—96% of the feed efficiency of maize (Noland, Campbell & Johnson, 1981; Moser, Peo, Moser & Lewis, 1982; Kemm, Ras & Daiber, 1984). Feed intake of sorghum-based diets is usually higher than that of maize diets (Tanksley, 1975; Kemm *et al.*, 1984), while sorghum-fed pigs gain as rapidly as those fed maize (Phillips & Ewan, 1977; Tanksley & Knabe, 1977; Hamilton, Orr & Tribble, 1979).

New varieties of sorghum are constantly being developed. Although most varieties have the ability to be produced efficiently under certain adverse environmental conditions, some have other characteristics which may improve their nutritional value (Peo, 1987). Several new yellow and hetero-yellow endosperm grain sorghum cultivars have been developed recently. They differ in chemical composition from the original cultivars (Hibberd, Hintz & Wagner, 1980) and may be equal to maize in nutritive value (Hale, 1986).

This experiment was conducted to evaluate a new hetero-yellow endosperm sorghum cultivar (G766W) in comparison to an original low-tannin sorghum cultivar (GL) as well as maize in a growth trial with pigs.

Experimental Procedures

Three experimental diets containing equal amounts of either maize, GL sorghum or hetero-yellow endosperm (G766W) sorghum were formulated. The experimental diets were composed to contain equivalent amounts of calculated digestible energy (DE), protein and lysine. The diets and their calculated nutrient composition are presented in Table 1.

Fifty-one Large White pigs (33 boars and 18 gilts) were randomly allotted to the three experimental diets. The diets were fed to 11 boars and 6 gilts per treatment. The trial started when the pigs were approximately 68 days of age and 19,2 ± 1,4 kg in live mass. The pigs were individually housed in flat deck-type cages, 1,6 × 1 m, fitted with a self-feeder and an automatic water nipple. Temperatures in the building were controlled to the extent that minimum temperatures never dropped below 20 °C, while maximum temperatures seldom rose above 30 °C. Pigs were fed *ad libitum* at all stages. Feed intake and live mass were recorded every seven days. Feed and water were withdrawn after mass

Table 1 Composition of the experimental diets an a DM basis

	Experimental diets		
	Maize-based diet	G766W-based diet	GL-based diet
Ingredient (%)			
Maize	63,94	–	–
G766W sorghum	–	63,94	–
Normal GL sorghum	–	–	63,94
Wheaten bran	17,60	17,70	17,70
Fishmeal	9,00	9,00	9,00
Soyabean oilcake	6,00	6,00	6,00
Feed lime	1,20	1,30	1,30
Fine salt	1,00	1,00	1,00
Monocalcium phosphate	0,90	0,68	0,68
Synthetic lysine	0,16	0,18	0,18
Minerals & vitamins	0,20	0,20	0,20
Nutrient composition (calc.)			
Protein (%)	18,1	18,1	18,1
Lysine (%)	1,0	1,0	1,0
Methionine & cystine (%)	0,7	0,6	0,6
Tryptophan (%)	0,23	0,23	0,23
DE (MJ/kg)	15,0	15,0	15,0
Crude fibre (%)	4,9	5,0	5,0
Fat (%)	5,0	3,9	3,9
Ca (%)	1,1	1,1	1,1
P (%)	0,9	0,9	0,9

determinations had been done. The experiment ended when the pigs were slaughtered at 83,8 ± 1,8 kg.

The model for the description of growth as proposed by Roux (1976) was used to calculate mean live mass-gains for the growth interval 30—90 kg live mass for each pig. The procedure followed for calculation of the data was described in detail by Kemm *et al.* (1984). A table of simple treatment means and appropriate significant levels of intake, growth and feed efficiency, calculated by the conventional method, is included (growth interval 30,3 ± 0,2 to 83,8 ± 1,8 kg). Differences between treatment means were tested for significance by multifactor analysis of variance (Snedecor & Cochran, 1980).

The DE contents of the different diets as well as the three grain components were determined by means of the mobile nylon bag technique (MNBT). Twenty bags per sample were used and the contents of four bags were pooled to get five energy values per sample. The technique used was described in detail by Brand, Badenhorst, Siebrits, Kemm & Hayes (1989).

Samples of the grain as well as of the composed diets were analysed for dry matter (DM) , nitrogen (N) , crude fibre (CF) and ether extract (EE) by standard AOAC methods (AOAC, 1984). The polyphenol content was determined by the modified Jerumanis procedure (Daiber, 1975). Gross energy (GE) determinations were carried out on a CP 400 adiabatic bomb calorimeter. Amino acid analyses, following acid hydrolysis in a sealed tube, were carried out with a Beckmann Model 6300 amino acid analyser.

Results and Discussion

The chemical composition and MNBT-determined DE values of the grain components and experimental diets are summarized in Tables 2 & 3. The amino acid compositions of the grain components and experimental diets are presented in Table 4.

Table 2 Chemical composition (DM basis) and MNBT-determined digestible energy values of the grain components

Ingredient	Gross energy (MJ/kg DM)	Chemical composition (%) DM	CP	EE	CF	Tannin	Digestible energy content (MJ/kg DM)
Maize	19,0	88,0	11,1	4,8	2,5	0,0	16,1 ± 0,6
GL sorghum*	19,0	88,0	13,3	2,9	3,5	0,4	16,6 ± 0,7
Hetero-yellow sorghum**	18,9	89,6	11,3	3,3	2,4	0,2	16,0 ± 0,8

* Normal endosperm sorghum.
** Cultivar G766W.

Table 3 Chemical composition (DM basis) and MNBT-determined digestible energy values of the experimental diets

Experimental diets	Gross energy (MJ/kg DM)	Chemical composition (%) DM	CP	EE	CF	Tannin	Digestible energy content (MJ/kg DM)
Maize	18,8	88,9	19,9	4,0	4,0	0,0	15,1 ± 0,5
GL sorghum*	18,5	89,9	21,2	2,9	5,5	0,3	15,2 ± 0,5
Hetero-yellow sorghum**	18,4	90,0	20,6	3,7	5,4	0,2	15,3 ± 1,4

* Normal endosperm sorghum.
** Cultivar G766W.

Table 4 Amino acid composition (DM basis) of the grain components and experimental diets

Item	Grain components			Experimental diets		
	Maize	G766W	GL	Maize	G766W	GL
Indispensable amino acids (%)						
Arginine	0,37	0,27	0,30	1,02	0,94	0,97
Histidin	0,23	0,20	0,22	0,44	0,43	0,42
Isoleucine	0,27	0,32	0,41	0,53	0,63	0,67
Leucine	1,05	1,31	1,61	1,44	1,68	1,72
Lysine	0,24	0,20	0,21	0,91	0,96	0,91
Methionine	0,20	0,20	0,19	0,33	0,30	0,31
Phenylalanine	0,43	0,52	0,61	0,74	0,86	0,86
Threonine	0,28	0,31	0,37	0,57	0,62	0,63
Valine	0,36	0,44	0,52	0,69	0,77	0,77
Dispensable amino acids (%)						
Alanine	0,62	0,93	1,11	1,01	1,22	1,28
Aspartic acid	0,54	0,71	0,83	1,33	1,39	1,51
Cystine	0,28	0,26	0,24	0,32	0,28	0,30
Glutomic acid	1,60	2,14	1,48	2,88	3,27	3,37
Glycine	0,30	0,31	0,33	0,80	0,79	0,80
Proline	0,74	0,81	0,93	1,01	1,66	1,04
Serine	0,40	0,48	0,57	0,70	0,76	0,81
Tyrosine	0,27	0,39	0,46	0,57	0,59	0,57

The CP contents of the GL sorghum, hetero-yellow endosperm sorghum and maize were 13,3, 11,3 and 11,1%, while the respective crude fat percentages were 2,9, 3,3 and 4,8%. The CF content was 3,5% for the GL sorghum, 2,5% for maize and 2,4% for the hetero-yellow endosperm (G766W) sorghum. The tannin content was 0% for maize, 0,4% for GL sorghum and 0,2% for G766W sorghum. The MNBT-determined DE contents did not differ significantly between the G766W sorghum (16,0 MJ/kg DM), GL sorghum (16,6 MJ/kg DM) and maize (16,1 MJ/kg DM).

The lysine content of maize (0,24%) was slightly higher than the lysine content of the G766W sorghum (0,20%) and that of the GL sorghum (0,21%). The same trend was observed in the case of methionine plus cystine content, where the value for maize (0,48%) was higher than those found for G766W sorghum (0,46%) and GL sorghum (0,43%).

Concerning the chemical composition of the experimental diets (Table 3), the determined CP contents for the GL sorghum diet (21,2%), G766W sorghum diet (20,6%) and the maize diet (19,9%) were higher than the calculated DM-basis CP content (Table 1) of 18,1%. The MNBT-determined DE values of the three experimental diets were almost the same as the calculated values. A slightly high standard deviation was found with the G766W diet, owing to one extremely high individual DE value. This may be the result of sample losses from the bags which contained the G766W diet.

Concerning the amino acid contents of the different experimental diets (Table 4), the actual determined lysine content values of the diets (0,91%, 0,96% and 0,91% for maize, G766W and GL sorghum, respectively) were slightly lower than the calculated value (1,0%/kg DM) for the diets. This phenomenon was also found in the case of methionine plus cystine, where the actual contents were found to be 0,66% (maize-based diet), 0,61% (GL sorghum diet) and 0,58% (G766W sorghum diet). These results suggest that the CP contents were slightly underestimated, while the lysine and methionine plus cystine contents of the ingredients used in the composition of the diets were slightly overestimated.

Table 5 Statistical parameters used in calculating the data presented in Table 6

Treatment	Statistical parameters				
	$\bar{\rho}$	$\bar{\alpha}$	$\bar{\mu}$	$\bar{a}$	$\bar{b}$
Boars					
Maize	0,904	9,040	6,449	−1,414	0,742
G776W	0,904	8,949	6,371	−1,395	0,737
GL	0,902	9,028	6,474	−1,243	0,708
Gilts					
Maize	0,904	8,889	6,501	−1,240	0,702
G766W	0,892	8,784	6,443	−1,120	0,688
GL	0,897	8,838	6,419	−1,101	0,682
Mean					
Maize	0,904	8,965	6,467	−1,405	0,728
G766W	0,899	8,891	6,396	−1,298	0,720
GL	0,900	8,962	6,455	−1,193	0,699

ρ = Slope of the autoregression; α = asymptote of cumulative DE intake; μ = mean initial ln (cumulative DE intake) value; b = mean slope of ln (live mass) — ln (cumulative DE) regressions; a = mean intercept of ln (live mass) — ln (cumulative DE) regressions.

Although the CP content of the GL sorghum diet (21,2%) as well as the CP content of the G766W sorghum diet (20,6%) was slightly higher than the CP content of the maize diet (19,9%), only small differences were found in the lysine and methionine contents. This is in agreement with the results found by Beames, Daniels & Sewell (1973) and Tanksley (1975). They found that the percentage of lysine changed only slightly (0,18 to 0,25%) when the CP content of sorghum increased from 6,5 to 13%.

The statistical parameters calculated from the growth data by the autoregression model are presented in Table 5. The growth, feed utilization and DM intake data calculated from this model are summarized in Table 6. Mean live mass-gain, feed conversion, and DM intake data calculated by the conventional method are presented in Table 7. It seemed that both types of caluculation, either by the autoregression model or by the simple conventional method, ranked the results in the same order, although only small differences occurred which may be attributed to the different growth intervals. Discussion of the results will therefore be done according to the results of the autoregression model in order to compare the diets for an equal growth interval.

It is clear from the presented data that no significant differences between the treatment means occurred. Pigs fed the hetero-yellow endosperm type sorghum had the highest avarage daily gains (ADGs), whereas pigs fed the maize-based diet had the lowest ADG values. The higher gains observed with the sorghum diets resulted from higher DM

Table 6 Means ± *SD* for growth, feed conversion and DM intake data calculated for the growth interval 30—90 kg live mass for 18 gilts and 33 boars of Large White-type pigs

	Diet		
Measurement	Maize	G766W*	GL sorghum**
Live mass-gain (g/d)			
Boars	839^{a} ± 84	888^{a} ± 63	857^{a} ± 70
Gilts	724^{b} ± 87	705^{b} ± 54	720^{b} ± 96
Treatment means	799 ± 100	824 ± 107	809 ± 102
	(100)	(103)	(101)
Feed conversion (kg/kg gain)			
Boars	2,75^{a} ± 0,20	2,74^{a} ± 0,23	2,89^{a} ± 0,63
Gilts	3,09^{b} ± 0,39	3,37^{b} ± 0,22	3,15^{b} ± 0,32
Treatment means	2,87 ± 0,32	2,96 ± 0,39	2,98 ± 0,53
	(100)	(103)	(104)
DM intake (g DM/d)			
Boars	2282 ± 179	2427 ± 126	2451 ± 441
Gilt	2219 ± 193	2373 ± 145	2249 ± 189
Treatment means	2260 ± 181	2408 ± 132	2380 ± 375
	(100)	(106)	(105)

a,b Denote significant ($P \leqslant 0{,}01$) differences in columns.

* Hetero-yellow endosperm sorghum.

** Normal endosperm low-tannin sorghum.

intake values. However, pigs fed the maize-based diet had the best feed conversion ration (FCR), while pigs fed GL sorghum had the lowest FCR. The ADGs and FCRs of the boars were highly significantly ($P \leqslant 0{,}01$) better than those of the gilts in all cases. Differences in DM intakes between boars and gilts were not significant.

Table 7 Means ± *SD* for growth, feed conversion and DM intake data calculated by the convential method (growth interval 30,3 ± 0,2 to 83,8 ± 1,8 kg)

	Diet		
Measurement	Maize	G766W*	GL sorghum**
Live mass-gain (g/d)			
Boars	861^{a} ± 51	907^{a} ± 57	869^{a} ± 49
Gilts	740^{b} ± 64	747^{b} ± 47	771^{b} ± 89
Treatment means	818 ± 80	851 ± 95	834 ± 80
	(100)	(104)	(102)
Feed conversion (kg/kg gain)			
Boars	2,61^{a} ± 0,16	2,61^{a} ± 0,20	2,82^{a} ± 0,61
Gilts	2,97^{a} ± 0,35	3,21^{b} ± 0,28	2,91^{b} ± 0,22
Treatment means	2,74 ± 0,29	2,82 ± 0,38	2,85 ± 0,50
	(100)	(103)	(104)
DM intake (g DM/d)			
Boars	2252 ± 205	2371 ± 136	2436 ± 485
Gilt	2193 ± 167	2399 ± 201	2231 ± 189
Treatment means	2232 ± 189	2381 ± 156	2364 ± 410
	(100)	(107)	(106)

a,b Denote significant ($P \leqslant 0{,}01$) differences in columns.

* Hetero-yellow endosperm sorghum.

** Normal endosperm low-tannin sorghum.

The results indicated a non-significant 1—3% better ADG, 5—6% higher DM intake and 3—4% poorer FCR for sorghum-fed pigs. This is in agreement with most of the results from the literature: Kemm *et al.* (1984) reported a non-significant 3—6% better ADG and 1—3% poorer FCR for sorghum-fed pigs; Serra, Oliveira & Fernandes (1982) found no significant differences in ADG or FCR when 20 and 40% maize respectively, was replaced by grain sorghum in diets for growing pigs; Hale (1986) reported ADGs of 860 and 900 g/d and FCRs of 2,99 and 2,90 kg/kg gain for a maize- and sorghum-based diet, respectively. Peo (1987), however, found pigs fed maize gained 3,9% faster and were 6,2% more efficient in feed conversion than those fed grain sorghum. Tanksley (1975) also found a significantly ($P \leqslant 0{,}05$) poorer FCR (3,21 versus 3,34) and a higher DM intake (2490 versus 2590 g/d) for sorghum-fed pigs, compared to maize-fed pigs, although no significant differences in ADGs (777 versus 773 g/d) were observed. Moser *et al.* (1982) found that pigs fed sorghum gained faster ($P \leqslant 0{,}05$), consumed more ($P \leqslant 0{,}05$) and had a poorer feed conversion ratio ($P \leqslant 0{,}05$) than pigs fed corn. Phillips & Ewan (1977) also found that sorghum, fed in addition to a basal diet, significantly improved gain but did not affect feed to gain ratio.

Concerning the influence of endosperm type, the results of this study differ from those reported by Tanksley (1975). He found a significantly ($P \leqslant 0{,}05$) poorer FCR with hetero-yellow grain sorghum when compared with non-yellow and yellow sorghum, although there were no significant differences in DM intake or ADG. Peo (1987) also indicated only small differences in ADG and FCR when comparing bronze, cream and yellow sorghum in growth trials with pigs.

Conclusions

Although the protein contents of the diets were different, there were only small differences in lysine and methionine plus cystine contents. There were no significant differences in DM intake, ADG or FCR of pigs fed either maize, normal endosperm low-tannin sorghum or a hetero-yellow endosperm sorghum cultivar in balanced diets, equal in DE and lysine contents. An indication of higher intake, better ADG and poorer FCR was, however, observed as expected. The hetero-yellow sorghum cultivar, G766W, was equal in nutritive value to maize as well as the GL sorghum cultivar.

It is concluded from this study that, provided that low-tannin grain sorghum of a good quality is used and provided that the diet meets the recommended dietary levels, it is possible to optimize pig performance.

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