A review on research performed in South Africa on small grains as energy source in pig diets+

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Introduction

At present, feeding contributes approximately 80% (P. Cornelius, Economics and Marketing Division, SAU, Pretoria) of the total cost of pig production in South Africa. Maize, traditional the main source of energy in pig diets in South Africa is produced mainly in the northern provinces of South Africa (summer rainfall area), which results in additional costs (approximately 20% - 30% of raw material cost) for transporting it to the Western Cape (winter rainfall area). Consequently, locally produced, small grains have been evaluated in a series of experiments as an alternative energy source compared to maize in pig diets. This manuscript contains a review of the research undertaken by the Elsenburg Agricultural Research Centre, the University of Stellenbosch and the Irene Animal Products and Research Institute in South Africa on the use of different types of locally produced small grains in diets of growing and finishing pigs.

Composition of small grains

In recent studies (Brand *et al.*, 1997, Brand 1998, Brandt, 1998) samples from 19 different small grain cultivars were collected from ten different localities in the Western Cape area of South Africa for three consecutive years (1994, 1995, 1996). The chemical (dry matter, ash, crude protein, acid detergent fibre, neutral detergent fibre and non-structural carbohydrates) and physical composition (hectolitre mass and thousand seed mass), as well as the digestible energy (DE) value of the samples were subsequently determined. Grain yield was also determined. The total crude protein (CP), and yield of the ten small grain types are presented in Table 1.Table 1 The mean (± SE) crude protein*, digestible energy* and yield of small grains produced in the Western Cape area of South Africa (Brand ***et al.,*** 1997; Brand, 1998; Brandt, 1998)

As far as the CP content is concerned, is it clear that the new types of naked (hull-less) grains have the highest values, followed by the traditional naked grains, while hulled grain has the lowest values. The low CP value of brewer's barley (cv Clipper) may be ascribed to the fact that it is selected for brewing purposes, which favoured a low CP value. The DE values of the grains follow a pattern similar to CP, with naked grain having the highest values, followed by hulled grain.

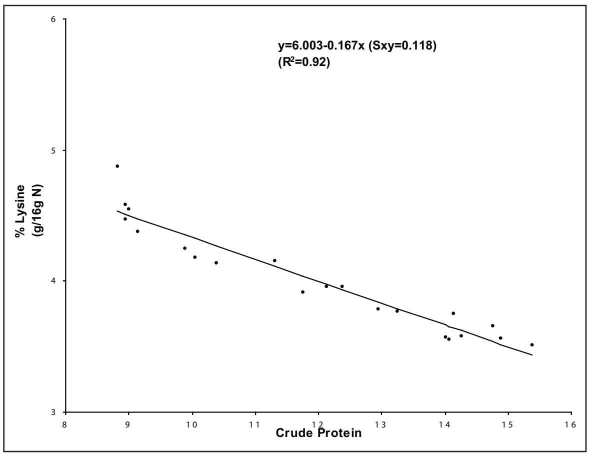

Figure 1 The relationship between protein and lysine (as % of protein) content of two-row brewer's barley (cv Clipper) (Brandt & Brand, 1997)

The exceptionally high DE value for naked oats may be ascribed to a high oil content (*ca* 9.7%). As far as yield is concerned, traditional naked grain generally has the highest value, followed by hulled grain, while the new naked grain types and common oats showed the lowest value. The value for small grains generally compares well with maize in terms of CP (10.2±0.6% on DM basis). A study by Kemm *et al.* (1986) including 112 wheat samples collected all over South Africa revealed a mean CP content of 17.5±2.65% and mean lysine content of 0.41±0.6%. The mean hectolitre mass of samples in this study (72.2±3.62 kg/l) was, however, lower compared to results obtained in the first study (77.9±4.6). Hectolitre mass is known to effect the CP content in wheat negatively.

Quality of small grains

In a follow-up study by Brandt & Brand (2000), the relation between the protein and amino acid content of wheat (cv Palmiet), barley (cv Clipper) and triticale (cv Usgen 19) was determined. A negative relationship was found between the protein and lysine percentage (as percentage of protein). The results indicated that the quality of protein decreases with an increase in the protein content of the grain. Figure 1 is an example of

Type of grain	CP (%)	Number of samples	DE (MJ/kg DM)†	Number of samples	Production (kg/ha)	Number of samples
Two-row naked barley	15.9.±0.4	36	-	-	1739±121	36
Naked oats	15.7±0.3	104	17.8±0.4	29	2080±113	103
Six-row naked barley	15.4±0.6	36	-	-	1735±101	34
Wheat/Triticale mixture	14.8±0.4	39	-	-	2985±164	39
Wheat (Bread baking type)	14.6±0.2	101	16.1±0.8	37	2827±93	101
Wheat (Feed type)	14.6±0.2	103	15.6±0.2	36	2940±104	103
Triticale	14.6±0.1	273	15.8±0.1	113	3046±66	271
Oats	14.4±0.1	310	12.6±0.1	115	1934±50	310
Six-row feed barley	13.6±0.1	337	14.4±0.1	115	2564±51	335
Two-row brewer's barley	13.5±0.2	103	14.8±0.1	36	2515±89	100

* DM basis
† Determined by the mobile nylon bag technique as described by Brand *et al*. (1989) and adjusted for overestimation by the regression equation: y = 1.998 + 0.788 x (Personal communication, F.K. Siebrits & E. Pieterse, Irene Animal Products and Research Institute, Private Bag X2, Irene 1675, South Africa)

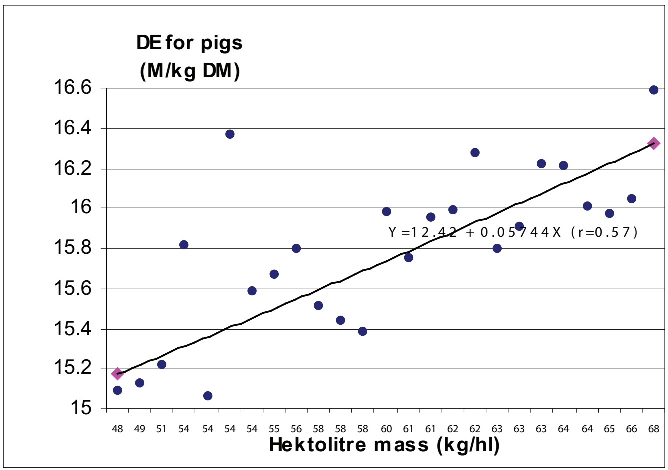

Figure 2 Points diagram to determine the relationship between hectolitre mass and energy value of barley (Brand & Swart, 1995)

the protein and lysine (as percentage of protein) content of barley.

In a recent study (Brand & Simon, 2000) the extract viscosity of three triticale cultivars from two different localities in South Africa were compared. Both cultivar as well as locality significantly ($P \leq 0.01$) affected extract viscosity (respectively 2.14, 3.07 and 3.88 mPas for the cultivars Usgen 19, Kiewiet and Rex).

Relationship between the chemical/physical characteristics and the energy value of barley

Brand & Swart (1999) undertook studies on the variation in the chemical composition of South African barley, as well as the relationship between energy value, chemical composition and physical properties. Comparisons were made to predict the energy value of barley from physical properties (hectolitre mass, percentage of screenings and amount of plump kernels) or chemical composition (crude fibre, acid detergent fibre or neutral detergent fibre). According to this study, it appears that considerable variation occurs in the physical composition, chemical composition, as well as the DE-values of barley for pigs. Both the physical and chemical properties can be used to predict the energy content of barley.

Growth studies with different types of small grains

Wheat

Kemm *et al.* (1986) conducted a study to compare the production performance of growing/finishing pigs consuming either a low-density wheat (67.5 kg/hl) or maize-based diet. Diets were formulated to be approximately equal in nutritional composition (12.8 MJ/kg DM, 18.6% CP and 0.80% lysine), while pig performance was evaluated during two growth intervals. They concluded from their study that pigs fed the wheat-based diet had live weight grains similar to pigs fed the maize-based diets. Pigs consuming the wheat-based diets utilized their feed 3-6% less efficiently, which decreased to 1-3% when compared on a DE intake basis (Table 2).

Triticale

The first growth study to evaluate triticale as energy source for pigs were undertaken by Horsten (1977). Two triticale cultivars with CP values of 8.5% and 14.5% respectively were used. In both cases maize was gradually substituted for triticale in balanced diets (13.7 MJ/kg DE; 17.4% CP; 0.95% lysine; 0.66% methionine plus cystine and 0.18% tryptophane) for growing pigs (18 - 45 kg).

No significant statistical differences occurred in dry material intake (DMI), average daily gain (ADG) and feed conversion ratio (FCR) between the diets (Table 3). Horsten (1977) concluded that triticale at these inclusion levels does not affect the taste of the diets or the production of the animals. The composition of carcass fat was also unaffected. Results obtained with chickens in the same study (according to net protein utilisation), however, indicate that although the protein content of triticale is higher than that of maize (14.5% vs 9.5%), the quality of protein is lower than that of maize.

Owing to varying results in practice, studies with triticale as an energy source in pig diets were repeated (Brand *et al*., 1995). Balanced diets in

Table 2 Production results of pigs fed either a wheat or maize-based diet (Kemm **et al.**, *1986)*

Diet	Average daily grain (g/d)	Feed conversion ratio (kg feed/kg grain)	DE conversion ratio (MJ/kg grain)
Growth interval 30-85 kg:			
Maize	694 (100)	3.02a (100)	39.3 (100)
Wheat	694 (100)	3.20b (10.6)	40.4 (103)
Growth interval 85-120 kg:			
Maize	576 (100)	4.73 (100)	61.4 (100)
Wheat	564 (98)	4.89 (103)	61.9 (101)

[a,b] Denote significant ($P \leq 0.05$) differences between treatments

Table 3 Production results of pigs (18 - 45 kg) that received different diets in which maize was gradually substituted for two different triticale cultivars (Horsten, 1977)

Diet composition (% in diet)	Dry matter intake (kg/d)	Average daily gain (g/d)	Feed conversion ratio (kg feed/kg gain)
Triticale (14.5% TRP):			
70 Maize: 0 Triticale	1.23	542	2.27
56 Maize:14 Triticale	1.32	570	2.32
49 Maize:21 Triticale	1.22	477	2.56
42 Maize:28 Triticale	1.23	502	2.45
35 Maize:35 Triticale	1.20	489	2.47
28 Maize:42 Triticale	1.27	517	2.48
21 Maize:29 Triticale	1.25	514	2.47
14 Maize:56 Triticale	1.33	549	2.41
Triticale (8.5% TRP):			
70 Maize: 0 Triticale	1.34	508	2.64
49 Maize:21 Triticale	1.38	556	2.65
42 Maize:28 Triticale	1.20	450	2.69
35 Maize:35 Triticale	1.26	492	2.56
28 Maize:42 Triticale	1.29	515	2.52
21 Maize:29 Triticale	1.26	466	2.71
14 Maize:56 Triticale	1.30	549	2.38

No significant differences occurred

Table 4 Production results of pigs (23 - 91 kg) on diets in which maize was gradually replaced by triticale (Brand et al., 1995)

Diet composition (% in diet)	Dry matter intake (kg/d)	Average daily gain (g/d)	Feed conversion ratio (kg feed/kg gain)
68 Maize: 0 Triticale (100:0)	2556^{a}±51 - (100)	944^{a}±25 - (100)	2.27±0.07 - (100)
46 Maize:27 Triticale (67:33)	2423^{ab}±49 - (95)	916^{ab}±24 - (97)	2.66±0.06 - (98)
23 Maize:54 Triticale (33:67)	2358^{b}±49 - (92)	849^{b}±24 - (90)	2.79±0.06 - (103)

^{a,b} indicate significant (P < 0.05) differences in columns

Table 5 Production data of pigs (20 - 50 kg) receiving diets in which maize was gradually replaced by barley (Kritzinger & Olckers, 1985)

Diet composition (% in diet)	Average daily gain (g/d)			Feed conversion ratio (kg feed/kg gain)		
	20-50 kg	50-70 kg	70-90 kg	20-50 kg	50-70 kg	70-90 kg
66 Maize: 0 Barley	714	848	827	2.46	3.09	3.02
44 Maize: 29 Barley	738	866	880	2.49	3.11	3.14
22 Maize: 58 Barley	742	877	851	2.50	3.07	3.12
0 Maize: 87 Barley	720	824	856	2.58	3.24	3.24

No significant differences occurred

which maize was gradually substituted for the triticale cultivar Usgen 19 (13.9 MJ/kg DE; 17.2% CP; 1.00% lysine; 0.69% methionine plus cystine and 0.23% tryptophan on a DM-basis) were compiled. These diets were fed *ad libitum*. to pigs.

Barley

In a study carried out by Kritzinger & Olckers (1985) four diets have been compiled (12.5 MJ/kg ME; 16% CP; 0.87% lysine and 0.63% methionine plus cystine) in which maize and maize-bran have been gradually replaced by barley.

The authors concluded that although production has not been inhibited by the inclusion of barley, a tendency was revealed that animals show a slower growth rate when consuming a diet with 87% barley. The results furthermore show that P_2 fat measures decrease with increasing levels of barley in diets (Table 5).

In a follow-up study with barley carried out by Olckers (1991), two balanced diets with either 70% maize or 90% barley respectively as sources of energy have been given to pigs (20 - 90kg). The ADG (814 vs 778 g/d) and FCR (3.34 vs 3.95 kg feed/kg mass increase) have not shown significant differences between the two diets. Back fat of carcasses of animals on the different diets did not differ significantly either.

Naked oats

In a study carried out by Brand et al. (1996) the value of naked oats, as an alternative to maize in diets of respectively weanling and growing/finishing pigs has been determined in two experiments. In both diets maize-meal and soybean oilcake meal have been gradually replaced with naked oats.

The production results of this experiment indicates that feed intake decreases linear (P < 0.01) with 198 (SEb=71) g/d for each replacement level of maize with triticale. Growth similarly decreased with 95 (SEb=34) g/day. Feed conversion and carcass characteristics have not been influenced by the diet (Table 4). Brand *et al.* (1995) concluded that triticale could replace up to 67% of the maize in a balanced diet, although the lower DMI and growth need to be taken into account. Both studies indicated substantial savings in terms of the addition of an external protein source, due to the higher CP value of triticale *vs* maize.

The inclusion of naked oats up to 71.5% in the diets of weanling pigs had no effect on FCR, ADG or time to reach their target weight. Weanling pigs on the high oats diet did, however, grow 10% slower than those on the remaining three diets (Table 6).

With growing/finishing pigs, both the ADG and the FCR have not been influenced by diet. There was, however, a tendency for ADG to decrease with 11.8 (SEb=8.3) g/d for every increment of oats inclusion in the diet. Pigs on the diets with 49% and 74% oats consumed approximately 7% (P < 0.05) less feed per day compared to pigs on the 100% maize-meal diet. The DMI, decreased linearly with 57.8 (SEb = 21.3) g/d (P > 0.01), with every increment inclusion of naked oats in the diet. Carcass data, such as percentage meat in the carcass, as well as the P_2 fat measures, has not been influenced by diet (Table 7). Brand *et al*. (1996) concluded that the levels of inclusion of naked oats above 49% might affect the production of weanling pigs negatively. The production of growing/finishing pigs has been affected to a lesser extent. As regards the maize-meal diet, an additional 108 kg/ton soybean oilcake meal had to be added to ensure an equal nutritional value compared to the naked oats diet. Apart from the higher protein content of naked oats, it also contains 4.1% lysine as a percentage of the protein compared to 2.8% lysine as part of the protein in maize.

Whole grain diets

In a study by Brand & Van der Merwe (1997) the production and metabolism of pigs receiving either a ground or a whole grain protein enriched diet, were determined (41.5% wheat, 41.5% barley, 17% protein source plus other additives). This was done to test alternative farming methods for small-scale farmers without access to milling and mixing equipment. As was expected, a lower production was attained with the whole grain diet (Table 8). Norms for production, however, could be established in order to advise smallholders, who do not have grinding facilities at their disposal.

Conclusions

The study revealed that locally produced small grains compare favourably with maize as source of energy. In most cases a somewhat lower production in terms of DMI and ADG with the inclusion of small grains at high levels in diets can be expected. The use of small grains, however, resulted in a possible saving in the addition of external protein sources. Results obtained in the South African studies generally corresponded to other international studies regarding the composition (Batterham *et al.*, 1980; Bourdon *et al.*, 1987; Champbell *et al.*, 1995; Leterme *et al.*, 1991; Morgan *et al.*, 1975; Rundgen, 1988; Wiseman, 1987) and quality (Batterham *et al.*, 1976; Fuller *et al.*, 1989; Radcliff *et al.*, 1986) of small grains. Although differences in proposed inclusion levels exist in some cases (Evans, 1987), production responses generally agreed with results obtained in other studies (Todorov, 1988).

According to the literature, it seems that restrictions on the level of certain small grains in diets may mainly ascribed to the presence of anti-nutritional factors. This include factors such as trypsin inhibitors, tannins, 5-alkylresorcinol (Evans, 1985), ergot contamination (Shimada *et al.,* 1974) and pentosans (arabinoxylans) (Antoniou & Marquart, 1981) in triticale, beta glucans in barley (Henry, 1985) and beta glucans (Morris, 1990) and pentosans (arabinoxylans) (Henry, 1985) in naked oats. The availability of an effective feed enzyme mixture (Simon, 1998, Vahjen & Simon, 1999) may, however, play an important role in future to improve the utilization of small grains, especially for young weanling and growing pigs.

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*Table 6 Production results of weanling pigs on diets in which maize and soybean oilcake meal were gradually replaced by naked oats (Brand **et al.**, 1996)*

Diet composition (% in diet)	Dry matter intake (kg/d)	Average daily gain (g/d)	Feed conversion ratio (kg feed/kg mass gain)
59 Maize-meal: 0 Oats	651ab±36	506±21	1.40±0.06
40 Maize-meal: 24 Oats	729a±20	522±20	1.41±0.05
17 Maize-meal: 48 Oats	703a±11	505±22	1.41±0.05
0 Maize-meal: 71 Oats	591b±43	461±23	1.39±0.03

[a,b] Denote significant (P ≤ 0.05) differences in columns

*Table 7 Production results of growing/finishing pigs (26 - 90 kg) receiving diets in which maize and soybean oilcake meal have been gradually replaced with naked oats (Brand **et al.**, 1996)*

Diet composition (% in diet)	Dry matter intake (kg/d)	Average daily gain (g/d)	Feed conversion ratio (kg feed/kg mass gain)
62 Maize-meal: 0 Oats	2358a	918	2.57
40 Maize-meal: 24 Oats	2239ab	896	2.51
21 Maize-meal: 49 Oats	2218b	888	2.50
0 Maize-meal: 74 Oats	2175b	879	2.48
Standard error	47	19	0.05

a,b Denote significant (P ≤ 0.05) differences in columns

Table 8 Production of growing/finishing pigs fed either a meal or whole grain composition for the growth interval 28-89 kg

Diet	DMI (g/d)	Average daily gain (g/d)	Feed conversion ratio (kg feed/kg mass gain)
Meal diet	2376a (100)	836a (100)	3.09a (100)
Whole grain diet	2190b (92)	742b (89)	3.40b (110)
SE	63	22	0.05

[a,b] Denote significant differences between columns

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