ADVANCES IN THE USE OF COTTONSEED MEAL IN DIETS FOR GROWING PIGS

E. S. BATTERHAM*

SUMMARY

Recent experiments have confirmed the low availability of lysine in cottonseed meal for growing pigs. This appears to arise from the processing conditions used to bind the free gossypol in the meal. It appears that portion of the lysine is absorbed in a form that is not utilized by the pig. There are indications that the other essential amino acids are affected in a similar manner. This decrease in amino acid utilization, rather than the residual free gossypol content of the meal, appears to be the main limitation to the value of cottonseed meal as a protein source for growing pigs.

INTRODUCTION

Cottonseed meal has been widely used as a protein concentrate for growing pigs. It is of medium protein content, but the protein is deficient in lysine, relative to the pigs' needs. Cottonseed meal contains gossypol, a pigment which is toxic to pigs. However, this is unlikely to be the major limitation to the use of cottonseed meal in diets for growing pigs. Rather, recent work has indicated that low availability and utilization of lysine and other essential amino acids poses a greater restriction on the value of cottonseed meal.

COMPOSITION OF COTTONSEED MEAL

Typical composition of cottonseed meal is given in Table 1. There are two main types of meal available - expeller extracted and prepress solvent extracted. Solvent extracted meal has less oil than expeller extracted meal, and the digestible energy content may also be lower.

Whilst the meal contains 32-45% protein, the amino acid profile is deficient in lysine, relative to the pigs' needs and to other higher quality protein concentrates. However, the concentrations of the other essential amino acids are reasonable, and thus there is considerable potential to markedly improve the quality of cottonseed protein with supplements of free lysine.

Cottonseed meal has a relatively high crude fibre content, and a low digestible energy concentration. This limits the use of cottonseed meal in high energy diets.

PRESENCE OF ANTI-NUTRITIONAL FACTORS

The major factor present is gossypol, a pigment in the seed which acts as a protectant against insect attack. During processing, heat is applied to render the majority of gossypol inactive by binding it within the meal. Not all the gossypol is bound and locally produced cottonseed meals contain 0.03-0.09% free gossypol. Free gossypol also reacts with iron sulphate, and this reaction can be used to inactivate gossypol in diets for growing pigs.

According to Tanksley and Knabe (1981) growing pigs can tolerate 100 ppm free gossypol in the diet before any adverse reactions occur. However, up to 500 ppm of free gossypol can be tolerated if ferrous sulphate is used to bind the free gossypol (in the weight ratio 1: 1 iron:gossypol). If one assumes that cottonseed meal contains 0.05% free gossypol, than up to 20% can be tolerated without the addition of iron sulphate,- and unlimited quantities with additional iron supplementation. For this reason, gossypol toxicity does not appear to pose a major limitation to the use of cottonseed meal in diets for growing pigs.

* North Coast Agricultural Institute, Wollongbar, NSW 2480.

TABLE 1 Composition of cottonseed meals*

Constituent	% (air-dry basis)
Crude protein	32–45
Dry matter	91–95
Crude fibre	8–14
Ether extract	1–6
Ash	6–7
Energy – gross – MJ/kg	17–20
– digestible – MJ/kg	9–14
Gossypol – total	0.8–1.5
– free	0.03–0.09
Amino acids	
Lysine	1.6
Threonine	1.3
Methionine	0.5
Tryptophan	0.5
Cystine	0.9
Isoleucine	1.2
Leucine	2.2
Tyrosine	1.1
Phenylalanine	2.0
Histidine	1.1
Availability of lysine (proportion of total)	0.40
Availability of other amino acids	Unknown

* Based on analyses of samples at Wollongbar

Cottonseed meal also contains cyclopropenoid fatty acids. They increase the ratio of saturated to unsaturated fatty acids in livestock by inhibiting the normal desaturation process during lipid synthesis in the livers of the animals (Allen et al. 1967). Whilst these fatty acids may have adverse effects in laying hens, in growing pigs the main effect is the deposition of saturated fatty acids in the carcass. This may be considered a disadvantage in the current climate where emphasis is placed on the inclusion of poly-unsaturated fatty acids in human diets. However, cottonseed meal could also be used to balance the effects of excessive dietary unsaturated fatty acids causing soft oily fat in pig carcasses. As the cyclopropenoid fatty acids are found in the residual oil content of the meal, prepress solvent extracted meal should contain lower concentrations than expeller extracted meals.

AVAILABILITY OF LYSINE

Unfortunately, the processing conditions used to inactivate gossypol also render much of the lysine unavailable to the pig. The availability of lysine in commercial meals is only 40% (Standing Committee on Agriculture, 1987). There appears to be no difference in types of processing, as the availability of lysine is similar in both prepress solvent and expeller extracted meals. This low availability, together with the characteristically low total lysine concentration, means that cottonseed meal only contains 0.6–0.8% available lysine, compared with approximately 2.5% in soyabean meal. This is a major limitation to the value of cottonseed meal for pigs.

STUDIES TO IMPROVE LYSINE AVAILABILITY

As the major limitation to cottonseed meal seemed to be protein quality, rather than residual free gossypol concentration, there appears to be potential to reduce the severity of the processing conditions. 'This could result in less loss in lysine availability but a corresponding increase in residual free gossypol concentration. The latter could then be inactivated by the addition of iron sulphate to the diet, if the free gossypol concentrations exceeded 100 ppm in dietary formulations.

In the processing of cottonseed, the seeds are conditioned, flaked, heated in the presence of water and steam to bind gossypol and aid oil extraction; passed through expellers to remove portion of the oil; extracted with solvent to remove additional oil and reheated to remove solvent and to further bind free gossypol if required, to reduce it to the desired concentration.

In this process, there appeared to be a number of areas where damage to lysine may occur – in the pretreatment prior to and during expeller extraction, and in the drying process following solvent extraction. Accordingly, work was undertaken with a commercial cottonseed meal processing plant to try to identify the effects of processing on lysine availability and to explore possible methods of relieving some of the damage.

In the initial experiment, it was decided to try to separate the damage done prior to solvent extraction from that done after solvent extraction.

Comparison of white meal, partially cooked and fully processed cottonseed meal for growing pigs

In . this experiment, the growth response of pigs fed diets containing white meal, partially cooked, and normally processed cottonseed meal, was compared with that of pigs given soyabean meal.

White meal is the name given to the meal after it has been solvent extracted. The meal was air-dried in the sun to remove excess solvent.

In the drying after solvent-extraction, the meal passes down a number of drying decks. For this work, the meal was removed after it had passed through the second deck. This was thought to represent minimal heating in this process to remove excess solvent but avoided further heating which might lower lysine availability.

The total and free gossypol contents of the three samples were respectively – white meal, 1.4 and 0.13%; second deck material, 1.3, 0.056%; cottonseed meal, 1.3, 0.057%. These results indicated that a substantial portion of the gossypol was bound prior to the solvent extraction, the remainder in the first two decks of the de-solventising dryer.

Approximately 20% of the three samples of cottonseed meal were included in wheat-based diets formulated to be lysine-deficient and fed restrictively to pigs over the 20–45 kg growth phase. Ferrous sulphate was added to inactivate any effects of the dietary free gossypol concentrations. A wheat-soyabean meal diet was formulated to a similar lysine content and used as a control. Results are presented in Table 2.

There was no difference in the performance of pigs fed the three samples of cottonseed meal. However, all results were inferior compared to pigs given the diet formulated from soyabean meal of similar lysine concentration.

These results indicate that: –

(a) the damage to lysine was occurring prior to solvent extraction,

(b) the pigs appeared able to tolerate the higher free gossypol concentration (plus iron sulphate> in the diet containing white meal and

(c) cottonseed meal was inferior to soyabean meal as a source of lysine for growing pigs. This latter result is in line with estimated lysine availabilities of 0.4 and 0.9 for cottonseed and soyabean meals, respectively.

Accordingly, experiments were conducted to determine whether it was possible to minimise damage to lysine availability by altering processing conditions prior to solvent extraction.

TABLE 2 The effect of stage of processing on the nutritive value of cottonseed meal for growing pigs

	Cottonseed meal			Soyabean meal	SEM
	White meal	Second deck	Full process		
Dietary free gossypol - ppm	254	112	114	-	
Pig response					
Gain - g/d	499	486	486	570	11
FCR	2.6	2.7	2.7	2.4	0.04
Backfat (P_2) - mm	13	13	12	13	0.6

Comparison of the availability of lysine in cottonseed meals of differing lysine concentrations

In this study, attempts were made to alter processing conditions prior to the expeller extraction of the meal. Initial studies indicated that there was only limited flexibility in the processing system. Reducing the moisture content resulted in a dry powdery product which didn't flow properly through the system that was designed to transport more moist material. Leaving the moisture content high but reducing the temperature resulted in very moist material which didn't flow at all. As a consequence, it was only possible to alter conditions so that the meals varied in free gossypol from 0.06 (normal meal) to 0.086% (experimental meal). The availability of lysine in the two meals, together with a soyabean meal, was then determined using a slope-ratio assay with growing pigs.

The availability of lysine in the meals was as follows - cottonseed meal (0.06% free gossypol) 0.27, cottonseed meal (0.086% free gossypol) 0.30, soyabean meal, 0.90.

These results confirmed the low availability of lysine in cottonseed meal and indicated that the alterations to processing conditions were minimal in regards to improving the damage done to lysine during processing. Overall, these studies indicated that there appeared little potential to reduce the damage done to lysine availability during processing, with the existing processing technology employed in Australia. Major design changes in the current systems or the introduction of alternative systems would seem necessary if meals of higher biological value for growing pigs are to be produced.

AVAILABILITY OF OTHER ESSENTIAL AMINO ACIDS IN COTTONSEED MEAL

The problem facing nutritionists is what value to allow for the availability of other essential amino acids in cottonseed meal. It is possible that lysine may be more affected than the other major essential amino acids; lysine is dibasic and undergoes Maillard type reactions in the presence of reducing sugars.

If this was the case, and the other essential amino acids were largely unaffected, then the quality of cottonseed meal protein could be restored by the inclusion of free lysine in the dietary formulations.

Determining the availability of the other essential amino acids by slope-ratio assays would be an extremely costly and time consuming undertaking. An alternative approach would be to determine whether the ileal digestibility of amino acids could be used to estimate availability. If it could, it would have the advantage that all nine essential amino acids could be determined in the one assay. Futhermore, the use of the ileal digestibility assay to estimate availability was suggested by Leibholz (1985a,b) who reported high recoveries of ileal digestible lysine and methionine in baby pigs. Accordingly, this technique was investigated for estimating the availability of a number of essential amino acids in cottonseed meal for growing pigs.

Ileal dieestibilitv of amino acids in cottonseed and sovabean meals

The apparent ileal digestibility of amino acids were determined in a prepress solvent-extracted cottonseed meal as well as in soyabean meal. The latter was included to act as a control. The results in Table 3 indicate that the ileal digestibility of most amino acids in cottonseed meal was slightly lower than in soyabean meal. This is in line with literature reports. However, it was interesting that the ileal digestibility of tryptophan was considerably lower in cottonseed relative to soyabean meal.

TABLE 3 Apparent ileal digestibility of the main essential amino acids and nitrogen in cottonseed meal and soyabean meal for growing pigs

	Cottonseed meal	Soybean meal	Significance
Lysine	0.74	0.89	**
Threonine	0.76	0.85	**
Methionine	0.79	0.91	**
Tryptophan	0.46	0.74	**
Nitrogen	0.78	0.85	**

Utilization of ileal digestible lysine

The initial experiment was conducted with lysine to ensure the technique was working before applying it to the other essential amino acids. Sugar-based diets were formulated with cottonseed meal or soyabean meal as the only source of lysine. Diets were formulated to 0.36 g ileal digestible lysine/MJ DE. Additional amino acids were added to ensure that lysine was the limiting amino acid. The pigs were fed restrictively over the 20–45 kg growth phase, and growth response and lysine utilization determined. Results are given in Table 4.

Gain/d and feed conversion were inferior in pigs fed the cottonseed meal relative to the soyabean meal diet. Only 28% of the estimated total lysine and 38% of the estimated ileal digestible lysine was retained in the empty bodies of pigs given cottonseed meal. In contrast 65 and 73% of the estimated total, and ileal digestible lysine intakes were retained by the pigs given soyabean meal. Using the availability values for cottonseed meal (0.4) and soyabean meal (0.89) as recommended by Standing Committee on Agriculture (1987) the estimated retention of available lysine was O.-7 and 0.73 for the pigs given cottonseed and soyabean meals respectively .

TABLE 4 Utilisation of ileal digestible lysine by growing pigs (preliminary results)

	Cottonseed meal	Soyabean meal	Significance
Dietary lysine – g ileal dig. lys/MJ DE	0.36	0.36	
Gain – g/d	377	541	**
Feed conversion ratio	3.5	2.3	**
Lysine retained			
: total lysine intake	0.28	0.65	**
: ileal digestible lysine intake	0.38	0.73	**
: estimated available lysine intake	0.70	0.73	

This experiment indicated that:-

(a) ileal digestibility values were unsuitable for estimating lysine availability as a considerable portion of the ileal digestible lysine was apparently not utilized, and

(b) only approximately 70% of the available lysine intake was retained by the pig. This indicates that approximately 30% of the lysine intake is utilized for other functions or is lost in protein turnover.

Utilization of ileal digestible threonine

This experiment was conducted in a similar manner as the lysine utilization experiment except that diets were formulated to be deficient in threonine. The experiment was conducted by Beech et al. (unpublished results). Results are in Table 5.

TABLE 5 Utilisation of ileal digestible threonine by growing pigs (preliminary results)*

	Cottonseed meal	Soyabean meal	Significance
Dietary threonine – g ileal dig. threo/MJ DE	0.22	0.22	
Gain – g/d	417	524	**
Feed conversion ratio	3.2	2.4	**
Threonine retention			
: total threonine intake	0.45	0.64	**
: ileal digestible threonine intake	0.58	0.76	**

* From Beech et al., unpublished data.

As with- lysine, growth rate and FCR were inferior in pigs given cottonseed meal relative to soyabean meal. Forty five percent of the total threonine and 58% of the ileal digestible threonine were retained by pigs given the cottonseed meal diet. In contrast, 64% and 76% of the total and ileal digestible threonine respectively, was retained by pigs given soyabean meal.

These results also indicate that ileal digestible threonine values do not reflect availability. However, the differences in retentions are less with threonine than lysine. If one assumes that the availability of threonine in soyabean meal is 0.85 (similar to the ileal digestibility value) then the availability of threonine in cottonseed meal is about 0.6. This indicates that threonine availability is less affected during processing than lysine.

Utilization of ileal digestible methionine

This experiment was conducted in a similar manner as the lysine utilization experiment, except that the diets were formulated to be deficient in methionine. At the time of writing this report only the growth data were available. Results are in Table 6.

TABLE 6 Utilisation of ileal digestible methionine by growing pigs (preliminary results)

	Cottonseed meal	Soyabean meal	Significance
Dietary methionine - g ileal dig. meth/MJ DE	0.09	0.09	
Gain - g/d	411	496	**
Feed conversion ratio	3.1	2.5	**

As with lysine, growth rate and food conversion ratio were inferior in pigs given cottonseed meal relative to soyabean meal.

These results also indicate that ileal digestible methionine values do not reflect availability. However, the differences in growth performances are also less with methionine than lysine. Thus it is probable that, as with threonine, methionine availability may be less affected during processing than lysine.

CONCLUSIONS

Recent research with cottonseed meal has indicated that tolerance to free gossypol concentrations in the meal does not appear to be a problem as regards inclusion levels for grower pigs. However, damage to amino acid availability during processing does pose a severe limitation on the economic value of cottonseed meal relative to free lysine and other protein concentrates.

Studies have indicated that the ileal digestibility of amino acids in cottonseed meal is not a reliable indicator of amino acid availability. It seems that portion of the ileal digestible amino acids are absorbed in a form that is not utilized. Thus there is a need to formulate diets on an available rather than total or ileal digestible amino acid basis.

There are also indications that whilst the availability of threonine and methionine are affected during processing, they do not appear to be depressed to the same extent as lysine. This indicates that there is a need for additional information on the availability of all the essential amino acids in cottonseed meal (and other protein concentrates), to enable accurate dietary formulations to be undertaken at least cost.

It is also doubtful that there is potential to reduce the damage done to the protein quality of cottonseed meal during processing with current .processing technology. It would seem that new processing systems, designed to minimise damage to amino acids whilst maintaining maximum oil quality and extraction are needed to be introduced before improvement could be made in this area.

ACKNOWLEDGMENTS

This work was supported by the Pig Research Council.

REFERENCES

ALLEN, E., JOHNSON, A.R., FOGERTY, AC., PEARSON., JUDITH A. and SHENSTONE, F.S. (1967). *Lipids*. 2 : 419.

LEIBHOLZ, JANE (1985a). *Br. J. Nutr.* 53 : 137.

LEIBHOLZ, JANE (1985b). *Br. J. Nutr.* 53: 615.

STANDING COMMITTEE ON AGRICULTURE (1987). "Feeding Standards for Australian Livestock-Pigs ". CSIRO, East Melbourne.

TANKSLEY, T.D. and KNABE, D.A. (1981). *Feedstuffs* p 24.