# COTTONSEED SUPPLEMENTS FOR SHEEP

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## SUMMARY

The effects of adding cottonseed oil (CSO) or whole cottonseed (WCS) to high fibre diets fed to sheep were studied. The addition of either CSO or WCS to the diet had very similar effects on rumen function. Rumen ammonia concentrations and protozoa1 populations were decreased by cottonseed supplementation and digestion of dry matter in the rumen was also lower. The addition of WCS to an oaten chaff diet resulted in a low production response and WCS is not recommended as a supplement for pastures which are providing a maintenance ration for grazing animals.

## INTRODUCTION

Supplementation of grazing animals is carried out during periods of pasture nutrient deficiency to enable animals to survive, to produce or reproduce. The aim of supplementation should be to maximise the efficiency of rumen fermentation and to balance the product of fermentation in accordance with the animals extra needs for bypass nutrients (Leng 1986). In addition the feeding of supplements should not result in a reduction in the intake of pasture. Traditionally Australian farmers depend on cereal grains as the major feed supplement during prolonged drought, however the rationale of unsupplemented grain feeding is perhaps questionable. Cereal grains have a high energy to protein ratio which is likely to result in an inefficient use of energy and in some instances can lead to metabolic disorders such as grain poisoning. Further it has been shown that when high starch cereal grains are fed to grazing stock the supplement substitutes for part of the diet formerly grazed (Allden and Tudor, 1976) and this is in part due to the concomitant decline in the number of cellulolytic bacteria in the rumen (Henning et al. 1980). In recent times widespread droughts in Eastern Australia have resulted in grain shortages and highlighted the need for more information regarding the use of alternative feeds such as the oilseeds. This report discusses some of the results from our initial studies with whole cottonseed and cottonseed meal supplements.

### Cottonseed and cottonseed meal

Although cottonseed is a by product of the cotton fibre, the processing of cottonseed is a major industry with world production of cottonseed exceeding 26 M tons in 1976 (Leah and Goldblatt 1980). Cottonseed oil is used almost exclusively for human consumption while cottonseed meal has been used as a major source of protein concentrate for ruminants in the U.S. for many years.

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Processing of cottonseed is generally carried out by one of three basic methods; screw pressing, prepress solvent extraction or direct solvent extraction. The solvent extraction methods result in a meal containing less than 1% oil while the screw press method leaves between 2.5-5% oil in the meal fraction. One of the main objectives of processing is to bind the natural occuring pigment gossypol into the meal fraction while preventing the pigments from being extruded into the oil. Cottonseed meal is high in protein (42%) however the presence of gossypol may reduce the biological availability of some amino acids (Damatay and Hudson 1975). While it is recognized that gossypol is toxic to monogastric animals it has not been implicated in problems with ruminants and in a recent study cows were fed a diet containing 55% whole cottonseed without any evidence of gossypol toxicity (Coppock et al. 1985).

Whole cottonseed (19% oil) is often used as a low cost means of increasing the energy density of rations fed to dairy cows. By nature of its oil content whole cottonseed has a higher energy content and is more digestible than cottonseed meal (Table 1) The short hairs (lint) covering the outside of the seed may cause some problems in handling and storing whole cottonseed. The composition of whole cottonseed and . cottonseed meal are shown in Table 1.

Table 1 Composition of whole cottonseed, cottonseed meal and some other commonly used feed supplements.

| Composition (%) | Whole cottonseed | Cottonseed meal | Wheat | Sorghum | Lupins |
|---|---|---|---|---|---|
| Digestibility | 79 | 65 | 87 | 80 | 79 |
| Crude Protein | 20 | 42 | 12 | 11 | 35 |
| Fat | 19 | 2 | 1.9 | 2.5 | 9 |
| Starch | 8 | 8 | 50 | 50 | 8 |
| Gross energy (MJ/kg) | 24 | 19.5 | 18.4 | 18.8 | 21 |

## Cottonseed oil and rumen function

Reductions in dry matter digestion (DM) in the rumen, methanogenisis, ammonia concentrations and changes in VFA proportions are frequently observed with the addition of oil to the diet (Palmquist and Jenkins 1980) and it is generally accepted that additions in excess of 4-5% of the diet are likely to be counter productive (Moore et al. 1986). The effects of oil appear to be due partly to the inhibitory activity by the long chain fatty acids released by hydrolysis in the rumen and partly to a physical coating of the feed particles preventing attachment of micro-organisms (Devendra and Lewis 1974). Our initial study examined the effects of cottonseed oil (CSO) supplementation of a low quality diet as most of the results reported in the literature have been obtained from animals fed low fibre diets rich in concentrates. Twelve mature Merino x Border Leicester sheep were fed a basal diet of ammoniated rice straw (ad lib) the diet also included 75g cottonseed, 50g lucerne, 1% urea and a mineral and vitamin mix.

Cottonseed was supplemented at four levels; 0,3,6 and 9% (as a percentage of straw intake). The results are presented in Table 2.

Table 2 Effect of cottonseed oil supplementation on fibre digestion and other rumen parameters in sheep fed straw based diets (Wolin 1986).

| Measurements | Level of cottonseed oil supplementation (% of straw intake) | | | |
|---|---|---|---|---|
| | 0 | 3 | 6 | 9 |
| In sacco digestibility (% D.M. lost from dacron bags suspended in the rumen) | | | | |
| $NH_3$-rice straw (36h) | $57^a$ | $55^{ab}$ | $52^{bc}$ | $51^c$ |
| Apparent digestibility | | | | |
| Whole tract | 42 | 44 | 41 | 42 |
| Rumen samples collected 4h after feeding | | | | |
| Total VFA concentration (mmol/l) | 82 | 72 | 75 | 92 |
| Molar proportions of VFA | | | | |
| acetate (%) | 74 | 73 | 73 | 71 |
| propionate (%) | $18^a$ | $18^a$ | $20^b$ | $23^b$ |
| butyrate (%) | $7^a$ | $8^a$ | $5^b$ | $5^b$ |
| Ammonia concentration (mg/l) | $197^a$ | $183^a$ | $115^b$ | $90^b$ |
| Protozoal population ($x10^4$/ml) | $15^a$ | $9^b$ | $3^b$ | $2^b$ |

* Values with different superscripts are significantly different ($P<0.05$)

Generally the 3% level of oil supplementation had little effect on rumen function which is consistant with other studies. When the diet was supplemented with 6-9% oil DM digestibility in the rumen was depressed (12%) and intake of rice straw was reduced by 20%. Rumen ammonia concentration and protozoa1 population density were also significantly lowered by the addition of oil to the diet. The proportion of propionate increased which resulted in a narrowing of the acetate: propionate ratio in the high oil supplemented groups. Although digestibility of DM in-the rumen declined apparent digestibility over the whole tract was similar for all diets which suggests that there was a shift in the site of digestion for the oil supplemented groups. Sutton et al (1983) reported a similar effect to the feeding to 6% linseed oil and coconut oil with a hay and grain concentrate diet. However it must be remembered that the added oil will be completely digested which means less basal diet was actually digested in the oil supplemented animals.

## Whole cottonseed and rumen function

A whole cottonseed supplement could be expected to supply both energy and nitrogen to the animal (see Table 1). As whole cottonseed is highly digestible it is believed most of the protein nitrogen is digested in the rumen along with the starch and some of the structural carbohydrates.

Therefore rumen microbes will be provided with both energy and nitrogen and in addition WCS will provide 'bypass' energy in the form of long chain fatty acids which are released in the rumen from the hydrolysis of the oil.

Our second study examined the effects of supplementing a low quality diet (oaten chaff) with two levels of WCS (75g and 150 g/d). A urea supplement was included in the experiment as a 'soluble nitrogen control*. Twelve mature Merino Border x Leicester sheep (3 animals/dietary treatment) were fed a basal diet of oaten chaff (intake of chaff restricted to 1.5% liveweight) and supplemented with either 10g/d urea, 75g/d WCS or 150g/d WCS. Minerals and vitamins were provided at 0.5% in each diet. The two levels of WCS provided cottonseed oil at approximately 2 and 4% of the diet. The results are shown in Table 3.

Table 3 Effect of whole cottonseed supplementation on fibre digestion and other parameters in sheep fed on oaten chaff based diet (Dicko 1986).

| Measurements | Diets | | | |
|---|---|---|---|---|
| | Basal | Urea 10 g/d | Whole cottonseed 75 g/d | Whole cottonseed 150 g/d |
| In sacco Digestibility (% DM lost from dacron bags suspended in the rumen. | | | | |
| Oaten chaff (36h) | 62[a] | 59[a] | 50[b] | 50[b] |
| Cottonwool (36h) | 36[a] | 46[a] | 39[b] | 11[b] |
| Apparent digestibility | | | | |
| Whole tract | 55 | 59 | 55 | 52 |
| Nitroben balance (gN/d) | 1.2[a] | 2.0[b] | 1.5[ab] | 2.7[bc] |
| As a % of N intake | 20 | 20 | 16 | 22 |
| Rumen samples (mean of 9 samples collected over 24h period) | | | | |
| Total VFA concentration (mmole/l) | 71[a] | 78[a] | 90[b] | 76[a] |
| Molar proportions of VFA | | | | |
| Acetate (%) | 71[a] | 70[a] | 65[b] | 64[b] |
| Propionate (%) | 19[a] | 20[a] | 23[b] | 26[c] |
| Buryrate (%) | 8[a] | 7[a] | 9[b] | 7[a] |
| Ammonia concentration (mg N/l) | 12[a] | 95[c] | 69[bc] | 53[b] |
| Protozoal population (x $10^4$/ml) | 31[b] | 74[a] | 18[c] | 1[d] |

* Values with different superscripts are significantly different ($P<0.05$)

Dry matter digestibility of oaten chaff was significantly reduced (20%) in the WCS supplemented animals and cellulolytic activity (as indicated by the digestion of cottonwool in sacco) was significantly lower when 150g WCS was included in the diet. The addition of urea did not significantly alter in sacco digestibility of DM and there was no difference between groups' for whole tract apparent digestibility which suggests there was a shift in the site of digestion in WCS supplemented groups.

Nitrogen balance was increased by all supplements as expected but there was no difference in the efficiency of nitrogen retention between the dietary groups. Whole cottonseed supplementation resulted in a narrowing of the acetate:propionate ratio in the rumen as was observed when cottonseed oil was added to the diet. The addition of urea to the diet increased the protozoa1 population while the addition of WCS greatly reduced the numbers of protozoa. Rumen ammonia concentration was increased by all supplements but both WCS diets were lower than the urea diet.

These results suggest that CSO and WCS have very similar effects on rumen function the only difference being that WCS influenced rumen function at a lower level of oil concentration (approx. 2% of diet). It is apparent from these studies that the inclusion of WCS in the diet is unlikely to stimulate the intake of basal diet and that digestion of the basal diet in the rumen is likely to be reduced. However the amount of energy available for microbial growth in the rumen may be similar (additional energy would be available from the digestion of WCS in the rumen) as total VFA concentration was not significantly altered by supplementation. The change in proportions of VFA (lower acetate and higher propionate) is interesting and suggests that supplementation has altered the composition and/or activity of the microbial population. This change could be brought about by the direct action of the oil on the bacterial population (medium to long chain fatty acids have been shown to be inhibitory to some rumen bacteria, particularly the cellulolytic bacteria (Henderson, 1973)) or by the reduction in protozoa1 numbers (low propionate producers) and subsequent increase in bacteria (high propionate producers). The low rumen ammonia levels in the WCS supplemented sheep could be the result of; lower production rate, increased rate of utilization or increased rate of absorption from the rumen. However, the latter was unlikely to be an important factor in these studies as rumen pH was similar for all diets, The increased ratio of bacteria:protozoa in the rumen is likely to result in a greater utilization of ammonia (protozoa do not use ammonia for synthesis of protein) and a lower production of ammonia (protozoa are highly proteolytic digesting dietary protein (Ushida et al.,1986) and bacterial protein (Coleman, 1975)). As consequence of this change more dietary and bacterial protein may flow to the duodenum an effect noted by Ikwuegbu and Sutton (1982) when linseed oil was added to the diet of sheep (Table 4). It is also interesting to note that there was an optimum level of linseed oil above which the duodenal flow of bacterial protein was less than the unsupplemented group. These authors concluded that oil may directly reduce the synthesis of bacterial-N but enhance synthesis through the reduction of protozoa, and it is the balance of these two processes which finally determines the outcome. Clearly productivity response relationships need to be established to determine the suitability of WCS as a feed supplement for sheep.

## Production from whole cottonseed and cottonseed meal

In this study a basal ration of oaten chaff was supplemented with three levels of WCS 75, 150 and 225 g/d and either 0 or 100 g of CSM. In addition to these six dietary groups there was a control diet (no supplement) and diets including 10 g/d urea with or without 100 g/d CSM. These diets were fed to second cross lambs (22 kg liveweight) for ten weeks. There were five animals in each dietary group and minerals and vitamins were provided at approximately 1% of the diet.

Table 4 Flow of bacterial-N and total non ammonia-N (NAN) at the duodenum of sheep given a basal diet (200 g/d hay and 400 g/d concentrate) alone or supplemented with 13, 26, or 40 ml linseed oil (Ikwuegbu and Sutton 1982)

| Flows at the duodenum | Linseed Oil (ml/d) | | | |
|---|---|---|---|---|
| | 0 | 13 | 26 | 40 |
| Total-NAN (g N/d) | 10.0[a] | 10.9[a] | 15.9[c] | 13.4[b] |
| Bacterial-N (g N/d) | 7.5 | 8.1 | 9.7 | 6.7 |
| Protozoal population in the rumen (x $10^4$/ml) | 372[a] | 211[b] | 9[c] | 1[c] |

* Values with different superscripts are significantly different (P<0.05)

A feature of this study was the large variation in WCS intake within each dietary group and it is apparent that adding more than 75 g of WCS to the diet did not increase the average intake of WCS (Table 5).

Table 5 Intake of whole cottonseed (WCS) by sheep offered an oaten chaff diet (ad lib.) supplemented with either 75, 150 or 225 g/d WCS and either or 100 g/d cottonseed meal.

| Level of cottonseed meal (g/d) | Level of whole cottonseed (g/d) | | |
|---|---|---|---|
| | 75 | 150 | 225 |
| 0 | 72 | 75 | 77 |
| 100 | 34 | 94 | 71 |

Responses to WCS supplementation were small and non significant (Table 6). Wool production increased from 2.3 g/d to 2.8 g/d live weight gain increased from 15 g/d to 38 g/d and intake of the basal decreased from 520 g/d to 470 g/d. A comparison of urea and WCS supplements indicates that urea was superior in promoting both intake of the basal diet and live weight gain while wool growth was similar for both supplements. (Table 6). The latter effect suggests that there was a more efficient conversion of dietary-N to wool in the WCS group since N-intake for this group was 8 g/d as compared to 13.3 g/d for the urea group. This increased efficiency is probably due to the reduction of protozoa in the WCS supplemented animals (Table 7) and concomitant increase in flow of' bacterial-N and dietary-N from the rumen. The removal of protozoa from the rumen has been shown to increase the flow of protein to the duodenum (Veira et al., 1983) and to increase wool growth (Bird et al. 1979). Wool production (+2 g/d), liveweight gain (+50 g/d) and intake of the basal diet (+100 g/d) were all significantly increased by the addition of 100 g/d CSM to the WCS diets. Production from the combination of either urea and CSM or WCS and CSM was similar.

Table 6 Dry matter intake (g/d), wool growth (g/d) and live weight gain of lambs given an oaten chaff diet supplemented with urea (10 g/d) or whole cottonseed* and either 0 or 100 g/d cottonseed meal .

| | Dietary group | | | | | |
|---|---|---|---|---|---|---|
| | No cottonseed meal | | | cottonseed meal (100 g/d) | | |
| | basal | basal + urea | basal +WCS | basal + urea | basal + WCS | |
| Dry Matter intake of basal diet (g/d) | 520 | 790 | 470 | 605 | 575 | |
| Contrasts | basal vs urea | | ***[**] | urea vs WCS | | *** |
| | basal vs urea+CSM | | n.s. | urea+CSM vs WCS+CSM | | n.s. |
| | basal vs WCS | | n.s. | no CSM vs CSM | | * |
| Wool growth (g clean wool/d) | 2.3 | 3.0 | 2.8 | 5.0 | 4.7 | |
| Contrasts | basal vs urea | | n.s | urea vs WCS | | n.s. |
| | basal vs urea+CSM | | *** | urea+CSM vs WCS+CSM | | n.s. |
| | basal vs WCS | | n.s. | no CSM vs CSM | | *** |
| Live weight gain (g/d) | 15 | 75 | 38 | 68 | 90 | |
| Contrasts | basal vs urea | | *** | urea vs WCS | | ** |
| | basal vs urea+CSM | | *** | urea+CSM vs WCS+CSM | | n.s. |
| | basal vs WCS | | n.s. | no CSM vs CSM | | * |

* As the intake of WCS was similar for each level of WCS supplementation, values for the three dietary groups were meaned.

** Level of significance * $P<0.05$, ** $P<0.01$, *** $P<0.001$

Table '7 Population density of protozoa in the rumen of lambs given an oaten chaff diet*(*ad lib.*) supplemented with urea (10 g/d) or whole cottonseed (WCS) and either 0 or 100 g/d cotton seed meal

| | Dietary group | | | | |
|---|---|---|---|---|---|
| | No cottonseed meal | | | cottonseed meal (100 g/d) | |
| | basal | basal + urea | basal +WCS | basal + urea | basal + WCS |
| Protozoal population x $10^4$ /ml | 25[a] | 33[a] | 1[c] | 10[b] | 2[c] |

* Values for WCS supplemented groups were meaned values
Values with different superscripts significantly different P<0.05.

## CONCLUSIONS

Despite the potentially high nutritional value of WCS, the addition of this feed to a basal diet of oaten chaff resulted in low production responses. It is important to note that in this study the basal diet provided a maintenance ration which would not be the case in many drought situations. The results suggest that the high oil content of WCS adversely interferes with rumen function, reducing digestion of fibre in the rumen and intake of the basal diet. The main advantages and disadvantages of feeding WCS to grazing animals are briefly summarised;

Disadvantages:

(a) Reduced intake of dry pasture
(b) Variable intake of WCS supplement (high number of non-eaters?)
(c) High intakes of WCS may be detrimental - results from the feeding study suggest that the wool production from animals consuming in excess of 100 g/d of WCS was lower than production from animals consuming between 60-80 g/d.
(d) Difficulties with handling and storage of WCS.

Advantages:

(a) Reduction of protozoa1 numbers in the rumen - it is possible WCS could be used in conjunction with an antiprotozoal chemical to eliminate protozoa from the rumen.

(b) Whole cottonseed may be useful when the feeding strategy is to provide a maintenance ration for example in a drought where pasture availability is low. In this situation reducing pasture intake may be an advantage and animals may accept the WCS supplement more readily because they are hungry.

Recommendation: Whole cottonseed is not a satisfactory supplement for pastures which are providing a maintenance ration for grazing animals.

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