EVALUATION OF JOJOBA MEAL AS A PROTEIN SOURCE FOR RUMINANTS

by

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STATEMENT BY AUTHOR

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The author would like to dedicate this thesis to his brother, Eduardo Cayetano. Without his help, encouragement and inspiration to have high standards of excellence, this study could never have been completed.

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ABSTRACT

Jojoba meal, either untreated (JM) or treated (TJM) by Lactobacillus acidophillus 629 (to reduce the content of cyclohexylglucosides) was compared to cottonseed meal (CSM) as a source of supplemental protein for ruminants. The jojoba meals were included at a level of 10% in complete mixed diets.

Results indicate the major limitation of jojoba meal as an ingredient for ruminant diets is its detrimental effect on feed intake. This was apparent in no-choice acceptability trials and two-choice preference studies with lambs and steers. Treatment of jojoba meal reduced, but did not eliminate, this effect.

However, the treatment process used apparently reduced digestibility of jojoba meal. A metabolism trial with steers showed digestibilities for protein and other major constituents in the TJM diet were lower than in CSM and JM diets.

INTRODUCTION

Jojoba (Simmondsia chinensis), a plant that is native to the deserts of the southwestern United States and northwestern Mexico, has attracted much attention during the last decade as a potential oil seed crop. Jojoba seeds contain approximately 50 percent of a liquid wax, commonly referred to as jojoba oil, which is equivalent or superior to sperm whale oil in all industrial applications for which it has been tested. It also shows economic promise for other applications, including use in cosmetics.

The economic value of most oil seed crops is due partly to the high protein meal which remains after extraction of the oil and which is utilized as a feedstuff for animals. The use of jojoba meal for this purpose is compromised by its low palatability and potential toxicity. These problems are apparently related to the content of cyanomethylenecyclohexyl glucosides, principally simmondsin and simmondsin-2'-ferulate, in the seeds.

Several methods, including chemical and microbiological methods, have been investigated as means to reduce the level of these compounds in jojoba meal. The objective of this study was to evaluate jojoba meal treated with

Lactobacillus acidophillus (629) to reduce the levels of potential toxicants, as a source of supplementary protein for ruminants.

LITERATURE REVIEW

General Characteristics of the Plant

Jojoba, *Simmondsia chinensis* L. Schneider, is an evergreen dioecious shrub classified in either the family Buxaceae or Simmondsiaceae (Sherbrooke and Haase, 1974). It is usually found at elevations of 300 to 1500 m; however, it occurs at sea level along the outer coast of Baja California and on the coast of Sonora, Mexico (Gentry, 1958). In this environment temperatures can reach nearly 50 C with no damage to the plant, but when temperature approaches 0 C reproduction is affected (Gentry, 1958).

Jojoba is a relatively hardy plant; in its native environment it is wind-pollinated and therefore does not require a specific insect pollinator. Its water requirements, which are not clearly established yet, are minimal and could easily be met with modest irrigation (Forti, 1973).

Interest in jojoba as a potential cultivated crop is due to the properties of the oil in the seeds. The oil, which is really a liquid wax because it consists of fatty acid esters other than glycerides, would appear to be an ideal substitute for sperm whale oil. Jojoba oil, in fact, has several inherent advantages over sperm whale oil. It

has no "fishy," unpleasant odor and comes in its natural state so pure that little or no refining is necessary. Jojoba oil is equivalent or superior to sperm whale oil in all industrial processes for which it has been tested (Scogin, 1977). Among the wide potential uses of the oil are lubricants, cosmetics, pharmaceuticals, polishing waxes and as a wax substitute (Ragless, 1979).

On the other hand, jojoba remains a wild plant. Genetically defined breeding stocks selected for maximum yields are not yet available (Yermanos, 1974). The behavior of the plant under intensive and extended exploitation, and the exact male and female ratio remains unclear.

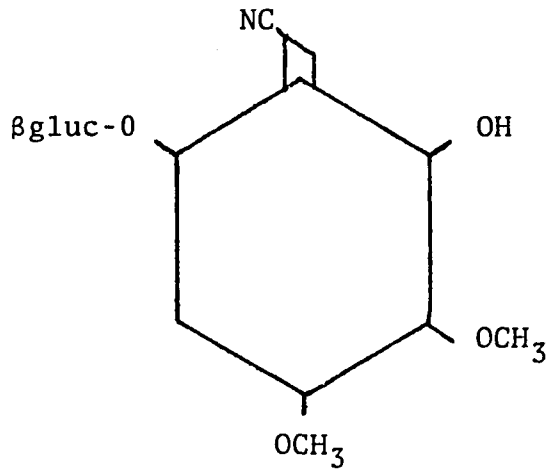
Acceptance of Jojoba Seeds and Meal by Animals

Booth and Ellinger (1973) offered laboratory rats diets containing 22% jojoba seed and 30 or 15% jojoba meal. All rats died within 2 weeks, probably from starvation. Diets containing lesser percentages of jojoba meal and of jojoba oil were reported to inhibit growth and cause testicular atrophy.

Weber (1973) found high mortality in weanling laboratory mice and reduced fertility in adult female mice fed diets containing 10% of jojoba meal.

Ellinger, Waiss and Lunden (1973) discovered and separated an unusual 2-cyanomethylenecyclohexyl glucoside,

cabled simmondsin, from jojoba seeds and demonstrated that this compound inhibited feeding in laboratory rats. The chemical structure of simmondsin is shown below.



Simmondsin

In 1974, Booth et al. proposed that jojoba toxicity probably results from metabolic conversion of simmondsin to a benzyl cyanide derivative, the latter having a far greater acute toxicity. When weanling rats were given a single oral dose of simmondsin at 4.0 g/kg body weight, no adverse effects were observed up to 14 days after dose. A single 3.6 g/kg dose of simmondsin administered intraperitoneally to mice was also non-lethal. However, when weanling rats were given oral doses of simmondsin at 750 mg/kg daily for five days, all rats lost weight and died within ten days after the initial dose.

Verbiscar and Banigan (1975) determined the nutrient composition of jojoba meal and hulls (Table 1) and reported that it also contained 4.5% simmondsin, 1% simmondsin-2'-ferulate plus at least two other minor, structurally related compounds. These investigators reported that simmondsin was not highly toxic in an acute dose but levels as low as .15% in the diet caused reduced food consumption by rats.

Not all animals are affected by simmondsin. Sherbrooke (1975) determined that one native rodent, Perognathus baileyi, readily consumed jojoba seeds and meal while three other species refused jojoba seed diets and lost weight rapidly. Apparently P. baileyi has a mechanism for detoxifying the cyanogenicglucosides found in jojoba seeds. It was hypothesized that jojoba seed toxicity is an important factor in resource allocation among coexisting seed-eating rodents in jojoba habitats.

Weber (1973) determined that jojoba oil itself can be an antinutritional factor. Jojoba oil was given to mice under chronic administration conditions. He concluded that jojoba oil seems to act as an intestinal lubricant, similar to mineral oil, and induced a diarrhea effect when included in the diet at more than 2%.

Table 1. Chemical composition of jojoba meal preparations.

Component	Untreated Meal	*L. Acidophilus* 629 Treated Meal	
		Preference and Acceptability Trial	Metabolism Trial
Moisture, %	4.8	6.1	6.0
Crude Protein, %	25.6	26.5	28.5
Ether extract, %	1.3	.8	1.2
Crude fiber, %	8.5	7.9	8.2
Nitrogen free extract, %	56.2	55.0	52.3
Ash, %	3.6	3.7	3.8
Simmondsin, %	4.2	.5	.12
Simmondsin-2'-ferrulate, %	1.3	.43	.2

Detoxification of Jojoba Meal

Several methods have been used in attempts to remove or modify the cyanogenic compounds in jojoba meal in order to make it palatable and nutritionally acceptable to animals.

The first step in any economic detoxification of jojoba meal is extraction of the oil to 1-2% (Verbiscar and Banigan, 1975). Dry or moist heat treatment reduces the bitter taste of jojoba, but not the toxicity which may even be enhanced. Heating apparently modifies simmondsin and simmondsin-2'-ferrulate but the degradation products still contain intact cyano groups.

Ellinger, Waiss and Booth (1974) reported that simmondsin and simmondsin-2'-ferrulate were reduced from 5.2 and 1.5%, respectively, to 0.05 and 0.01% when jojoba meal was wetted and treated with ammonia for 40 days in a closed container. In order to reduce the toxicant levels in the meal, solvent extraction has been accomplished using different solvents such as methanol, acetone, isopropanol and methylene chloride: methanol. Water extractions have also been used in which the meal is first treated with phosphoric acid, or boiled briefly, to precipitate water-soluble protein, thereby facilitating filtration.

Animal Studies with Jojoba Meal

Reid (personal communication, 1979) conducted experiments with broiler chicks to evaluate various jojoba meal

preparations. Nondetoxified meal and meals treated with ammoniacal hydrogen peroxide, or boiling water were tested. In these experiments the jojoba meals were added to diets at 5% and 10% levels. The chicks did not do well and high mortality occurred on non-treated meal at 10%. The ammoniacal hydrogen peroxide treated meal compared well with controls at the 5% level, but performance was reduced at the 10% level. On water extracted meal the chicks did not do well, perhaps due to loss of nutrients in the water. Simmondsin and simmondsin-2'-ferrulate contents in the meals were: untreated, 4.2 and .5%; ammoniacal hydrogen peroxide treated, .05% and trace; and water treated, .08% of each.

Trei and Nelson (1979) conducted several trials with deoiled, but non-treated jojoba meal in diets for sheep.

In trial I, hexane deoiled meal fed at 10% for 24 days caused a lower feed intake (4.2 versus 4.0% BW for control and jojoba, respectively) and decreased efficiency compared to basal cottonseed meal ration.

In trial II methylene chloride deoiled meal fed at 10, 20 and 30% of the basal ration resulted in very significant restrictions in feed consumptions compared to basal 10% cottonseed meal ration. Gains and efficiency decreased with increasing jojoba meal intake. Subsequent preference trials with lambs confirmed the apparent palatability or feed

consumption problems with the methylene chloride deoiled but non-treated jojoba meal. However, there were no differences in blood constituents or in the tissue sections of lambs sacrificed after 35 days on feed or those autopsied at the termination of the 98-day feeding period. All lambs on the jojoba rations consumed their feed reluctantly the first few days and lost weight over the first week of the experiment.

There was a gradual adjustment to increased feed intake for the lambs fed the experimental jojoba meal which was most pronounced during the first week of the trial. However, even in the last 63 days of the trial, consumption of the jojoba meal diet averaged 1.16 kg per head per day versus 1.83 kg for the 10% cottonseed meal basal diet.

In trial III the substitution of methanol deoiled but non-treated jojoba meal in place of cottonseed meal also reduced feed consumption, rate of gain and efficiency, although, the voluntary reduction in feed consumption on the experimental meal was not as severe as in trial II.

Analyses of fecal matter from jojoba meal fed lambs showed only trace amounts of the two major toxicants, calculations indicated a 99% reduction of the toxicants from feed to feces. Subsequent <u>in vitro</u> incubations of non-treated jojoba meal with rumen microorganisms confirmed the disappearance of simmondsin after a 12-hr fermentation period.

These authors concluded that the toxicity of jojoba meal was considerably lower to ruminants than to poultry or mice, probably because of rumen microbial metabolism of simmondsin and related toxicants. Nevertheless, the reduced voluntary feed consumption and reduced efficiency with the non-treated jojoba meals definitely limit their utility in ruminant rations.

METHODS AND MATERIALS

Jojoba Meal Preparations

All jojoba meals used in these studies were provided by Anver Bioscience Design, Inc., Sierra Madre, California. Starting material for these preparations was an expeller processed meal obtained from the San Carlos Apache Tribe, San Carlos, Arizona. This meal was solvent extracted with hexane at the Angola Soya Company, Angola, Indiana. Extracted meal was desolventized in steam-jacketed drying units at 90-120 C for about 45 minutes. This heat treatment deactivated the natural enzymes in jojoba meal which can cleave the glucose from simmondsin in aqueous medium.

Treated jojoba meal was prepared by incubating the solvent extracted meal with Lactobacillus acidophilus 629. Treated meals were prepared in 100 kg batches. An ammoniated innoculum of L. acidophilus 629 in 40ℓ of skimmed milk was sprayed on 100 kg of jojoba meal and allowed to stand at 26 C for 21 days in a closed container. The meal was then ground to pass a 4 mm screen in a hammer mill and dried for about 20 hr in a forced-air oven at 75 C, resulting in a moisture level of approximately 6%. Details of the treatment procedure have been given by Verbiscar (personal communica-

tion, 1981). Proximate and cyanoglucoside analyses of the meals used in these studies are in Table 1.

Preference Trial

Twelve beef steers of mixed breeding (mean initial weight 230 kg) and twelve cross-bred lambs (mean initial weight 40 kg) were randomly allotted to three treatment groups and assigned to a choice of diets supplemented with either: (1) untreated jojoba meal (J-109) or cottonseed meal; (2) Lactobacillus acidophilus 629 treated jojoba meal (J-176 drums 2 and 3) or cottonseed meal; (3) treated jojoba meal or untreated jojoba meal. Ingredient composition of the diets is shown in Table 2. The diets were pelleted (1 cm diameter) to avoid sorting of ingredients.

For the duration of this study, the steers and lambs were confined to individual pens with feed bunks divided into two compartments. During a 7-day preliminary period, all steers and lambs were fed ad libitum a non-pelleted diet similar in ingredient composition to the experimental diets, but without any source of supplemental protein. Following the preliminary period, a 14-day experimental phase was conducted in which each diet in a choice was provided in sufficient quantity to satisfy each animal's voluntary intake. All animals were fed twice daily and positions of diet choices in the bunk were alternated at each feeding in order to avoid positional bias.

Table 2. Ingredient composition of pelleted diets for preference trial 2.

Ingredient	Percent As Fed Basis
Sorghum grain, ground	52.20
Cottonseed hulls	20.00
Alfalfa hay, ground	10.00
Test meal[a]	10.00
Molasses, cane	6.00
Animal fat	1.00
Dicalcium phosphate	.55
Trace mineral salt	.25
Vitamin A, IU/kg	3300
	100.00

[a]Either cottonseed meal, treated jojoba meal (J-176) or untreated jojoba meal (J-109).

Acceptability Trial

After completion of the preference trial, steers and lambs were re-assigned from within previous treatments to three groups in order to determine voluntary intake of the pelleted diets when no choice was given. Ad libitum feed intake was recorded for 35 days for steers fed the treated jojoba meal and cottonseed meal diets, and for 63 days for steers fed the untreated jojoba meal diet. Because of previous commitments the lamb trials could be continued for only 14 days.

Metabolism Trial

After the acceptability trial, the steers remained on the same treatments for determination of diet digestibilities and nitrogen balance. The pelleted diets used were the same as described previously except the cottonseed meal diet was reformulated (cottonseed meal decreased to 5.00% and sorghum grain increased to 57.20%) to make it more similar in nitrogen content to the jojoba meal diets.

Collections were made first from steers on the treated jojoba meal and cottonseed meal diets. Intakes were restricted so that mean daily intakes of dry matter and nitrogen were similar for both diets. The controlled intake regimen was followed for 21 days prior to placing steers in metabolism crates for 5-day total collections of feces and

urine. An aliquot of the daily fecal excretion was dried at 50 C in a forced-air oven for 48 hours. Dry samples for each steer were pooled and ground through a 1-mm screen with a Wiley mill and a portion of the ground composition was retained for analysis. Urine was collected in plastic containers to which 50 ml of hydrochloric acid diluted 1:1 with water had been added. Daily urine collections were brought to a constant weight with water and a 2% aliquot was retained. Daily aliquots were composited and stored under refrigeration until analyzed. Samples of the feeds taken during the collection period were ground through a 1-mm screen and an aliquot retained for analysis.

Upon completion of the first set of collections, steers fed the untreated jojoba meal diet were placed in the crates and collections of feces and urine made as described for the other two diets. One steer on this treatment, because of his temperament, was not used in this phase of the study and, consequently, values for this treatment are means of three steers.

Nitrogen, final dry matter, ether extract and ash determinations were made on appropriate samples using A.O.A.C. (1970) methods. Gross energy was determined in a adiabatic bomb calorimeter.

Statistical Analysis

Analysis of variance and Duncan's Multiple Range Test (Steel and Torrie, 1960) were used for statistical treatment of data. The 5% level of probability was used to denote statistical significance.

RESULTS

Preference Trial

The intake data are presented in Figures 1 and 2. When steers were given a choice between diets containing untreated jojoba meal or cottonseed meal, a definite preference was shown for the cottonseed meal diet which comprised 83% of the total daily intake. No diet preference was observed when choices were between diets containing treated jojoba meal or cottonseed meal and treated jojoba meal or untreated jojoba meal. Total daily feed intake was lower ($P < .05$) for steers which had only untreated jojoba meal or treated jojoba meal diets available (4.0 kg) than for those for which the cottonseed meal diet was one of the choices (5.9 kg).

Lambs were more discriminating than steers. For the choice between cottonseed meal and untreated jojoba meal diets, 93% of the total intake was from the cottonseed meal diet. In the comparison between cottonseed meal and treated jojoba meal diets, 81% of the intake was from the cottonseed meal diet. In the choice between diets supplemented with treated jojoba meal or untreated jojoba meal, lambs almost entirely excluded the untreated meal diet which made up only

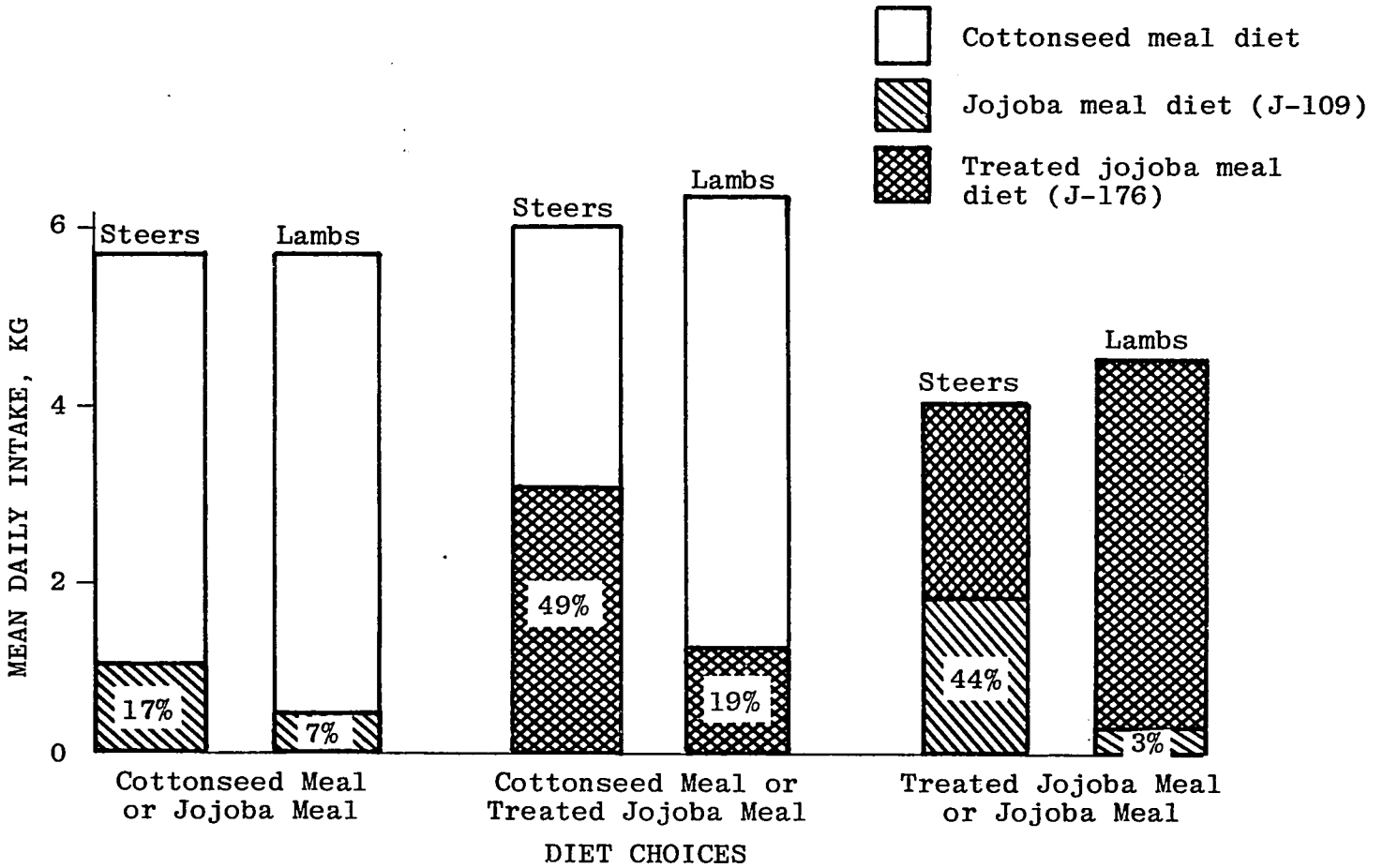


Figure 1. Summary of intakes by steers and lambs offered diet choices in preference trial 2 (pelleted diets). -- Lamb intakes have been multiplied by three to put on the same scale as the steers.

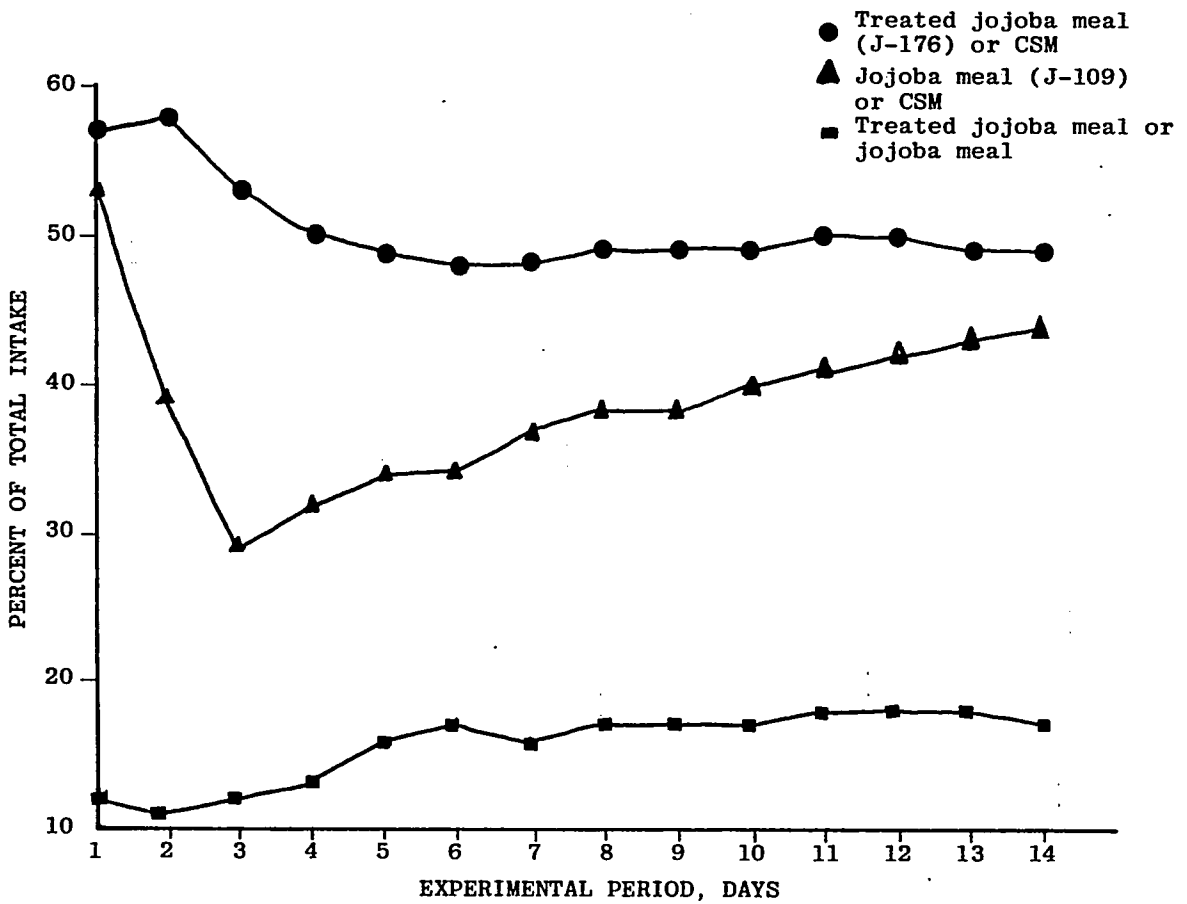


Figure 2. Contribution of least preferred diet choice to total intake by steers in preference trial 2 (pelleted diets).

3% of the total daily intake. Despite this discrimination, total intake on this latter treatment was less ($P < .05$) than on the treatments in which the cottonseed meal diet was one of the choices.

Acceptability Trial

Intake data for steers during this no-choice period are shown in Figure 3. For the first 5 weeks, mean daily intakes averaged 6.6, 5.0 and 3.3 kg for cottonseed meal, treated jojoba meal and untreated jojoba meal diets, respectively. Since intake of the untreated jojoba meal diet appeared to be increasing during the first 5 weeks, it was fed for an additional four weeks during which time intakes continued to improve, reaching a high of 5.0 kg/day. Mean intake of this diet during these last four weeks was similar to that attained during the first five weeks by steers fed the treated jojoba meal diet.

Results of the 14-day lamb trial are shown in Figure 4. As with the steer trial, intake was highest on the cottonseed meal diet and lowest on the untreated jojoba meal diet.

Metabolism Trial

Chemical composition of the diets used is in Table 3. Crude protein content was slightly lower in cottonseed meal

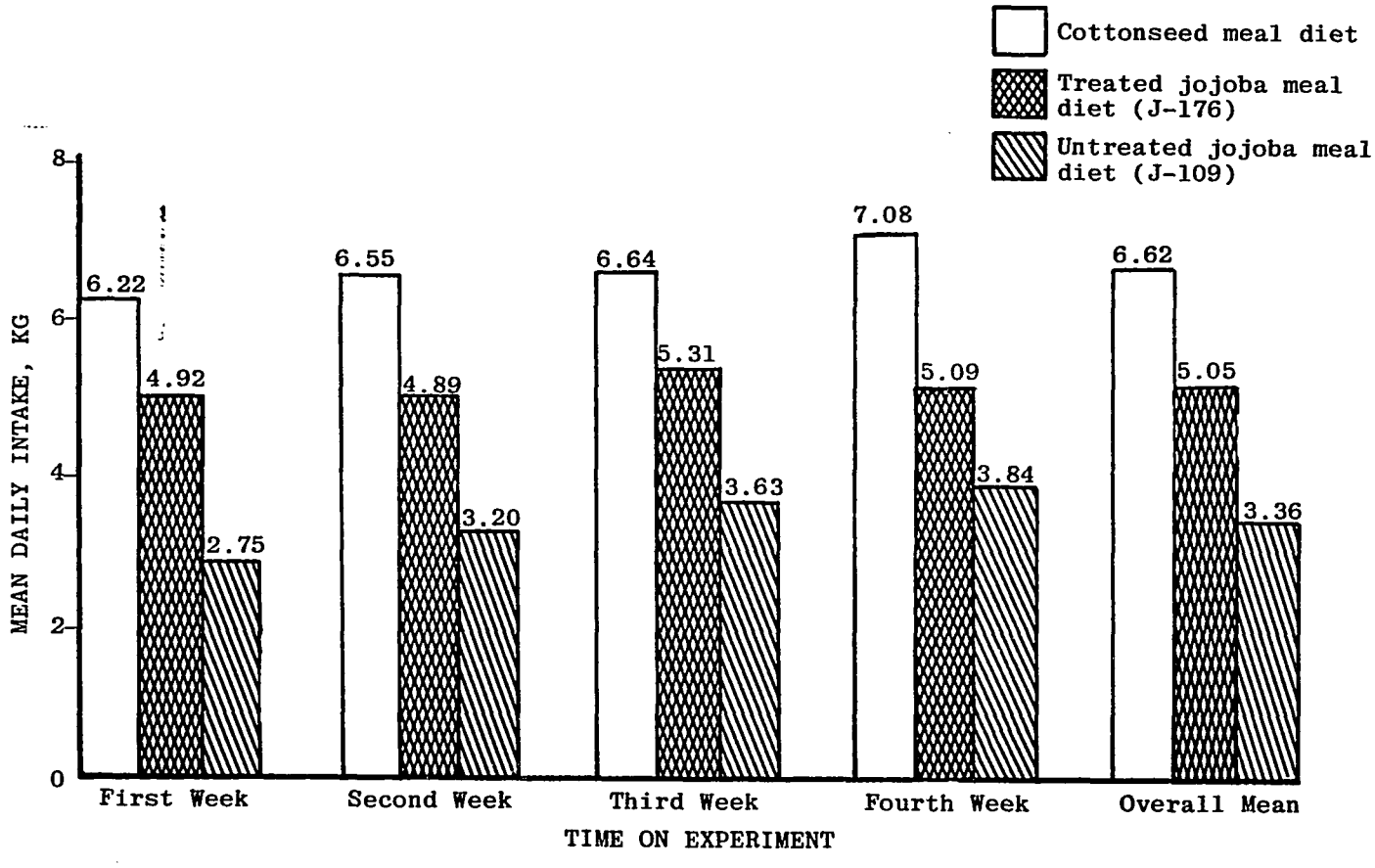


Figure 3. Mean daily intake of pelleted diets by steers in no-choice acceptability trial.

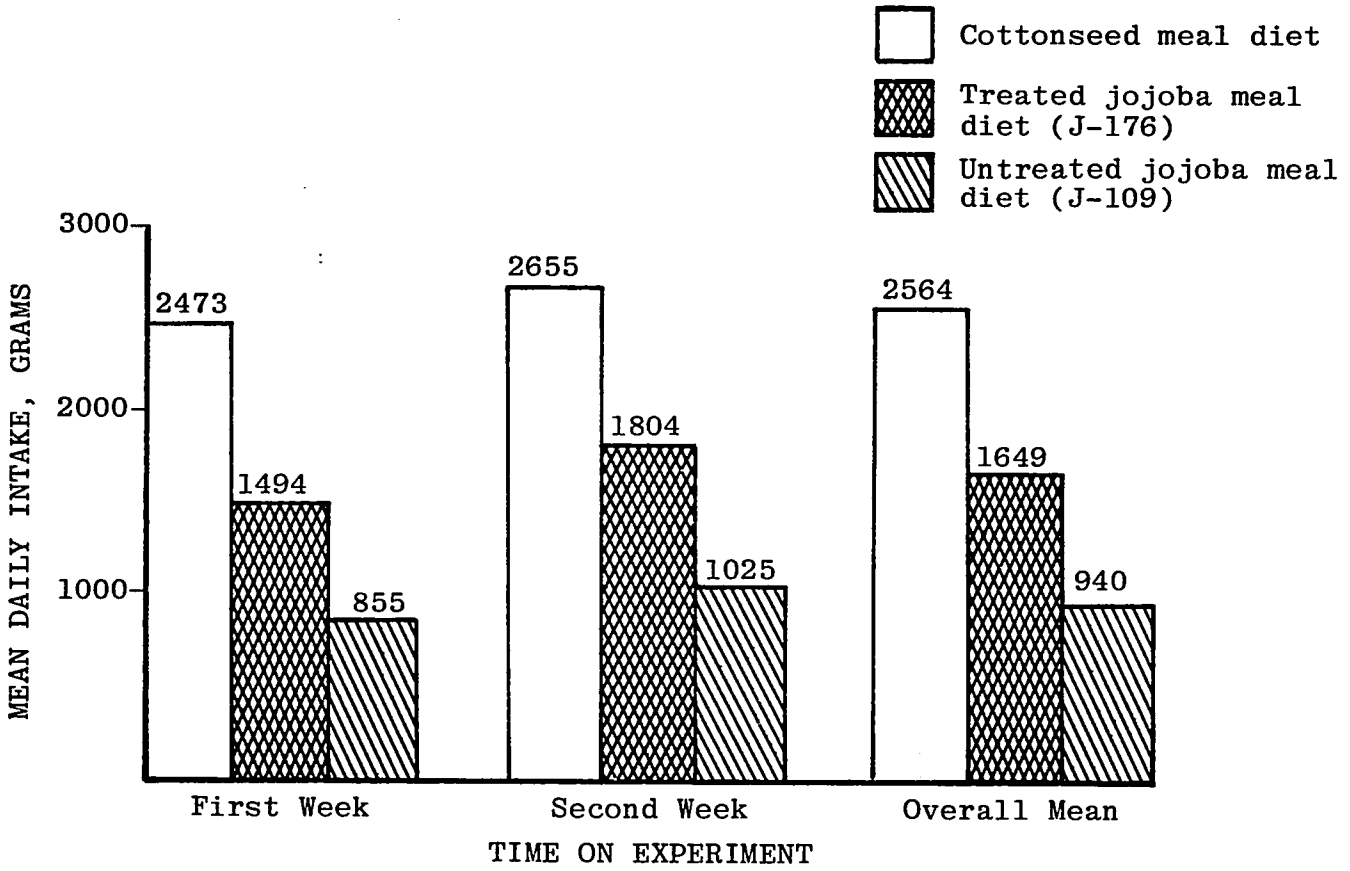


Figure 4. Mean daily intake of pelleted diets by lambs in no-choice acceptability trial.

Table 3. Chemical analysis of pelleted diets used in the nitrogen balance trial.[a]

Component	Source of Supplemental Protein		
	Treated Jojoba Meal	Cottonseed Meal	Untreated Jojoba Meal
Nitrogen, %	1.78	1.68	1.75
Crude protein, %	11.1	10.5	10.9
Ether extract, %	2.4	3.3	2.1
Ash, %	6.4	5.4	6.7
Gross energy, mcal/kg	4.39	4.47	4.42

[a]Dry matter basis.

than in the jojoba meal diets but all values were between 10.5 and 11.1%. Intake, nitrogen balance and apparent digestibility data are in Table 4. Dry matter and nitrogen intakes were similar ($P < .05$) for the treated jojoba meal and cottonseed meal diets. However, intake values for these treatments were lower than for the untreated jojoba meal diet.

Nitrogen retention as a percentage of nitrogen intake was lower for the treated jojoba meal diet (19%) than for either the cottonseed meal (22%) or untreated jojoba meal (23%) diets. When expressed as a percentage of nitrogen apparently absorbed, nitrogen retention for steers fed the treated jojoba meal diet was similar to that for steers fed cottonseed meal.

Apparent digestibility of nitrogen in cottonseed meal and untreated jojoba meal diets was approximately equal and both were higher than treated jojoba meal, 52.0, 51.1 and 46.8%, respectively.

Apparent digestibility of dry matter in the cottonseed meal diet was higher (71%) than that in untreated and treated jojoba meal diets (68 and 67%, respectively). Differences in organic matter digestibility were very similar, 72% for cottonseed meal, 70% for untreated and 68% for treated jojoba meal. Gross energy digestibilities are also

Table 4. Mean daily dry matter intake, nitrogen balance and apparent digestibilities by steers fed pelleted diets containing treated jojoba meal, untreated jojoba meal or cottonseed meal.

Item	Source of Supplemental Protein		
	Treated Jojoba Meal[a]	Cottonseed Meal	Untreated Jojoba Meal[b]
Number of steers	4	4	3
Dry matter intake, g/day	4945	5135	5545
Nitrogen balance, g/day			
Intake	88.0	86.3	97.1
Fecal	45.9	41.1	48.0
Urinary	25.1	25.5	26.1
Retained	17.1	19.7	23.0
% of intake	19.0	22.4	23.4
% of absorbed	41.1	42.8	47.1
Apparent digestibility, %			
Nitrogen	46.8	52.0	51.1
Dry matter	67.4	71.4	68.6
Organic matter	68.9	72.5	70.2
Gross energy	66.6	70.9	68.5
Ether extract	71.7	80.0	72.2

[a]Treated with L. acidophilus 629 (J-176 drums 2, 3).

[b]Deoiled jojoba meal (J-109).

included in Table 4: cottonseed meal, 71%; untreated jojoba meal, 68%; and treated meal, 66%. Ether extract apparent digestibility was higher for the cottonseed meal (80%) and lower but similar for untreated and treated jojoba meal diets, 68% and 66%, respectively.

DISCUSSION

It is clear from the research presented that the primary problem with jojoba meal as a potential feed ingredient for ruminants is its depressing effect on feed intake. This effect was evident from the very first exposure of lambs and steers to diets containing untreated jojoba meal, suggesting it is due to some sensory component (either smell or taste) rather than to metabolic injury.

One practical use of jojoba meal possibly would be in supplements for range livestock. In critical range conditions, such as drought, jojoba meal could prove to be a useful feed ingredient which animals, offered no alternative, would accept. A reduced acceptability might even be advantageous under these conditions since livestock frequently consume more supplement than is desirable unless intake is regulated in some manner. Under these conditions maintenance of the cattle, rather than weight gain, is the important emphasis.

For other applications, such as in diets for growing-fattening beef cattle, maximum feed intake is of primary importance and thus reduction, if not elimination, of the apetite depressing factors in jojoba meal would be essential.

In this study intake of the diet containing jojoba meal treated with L. acidophilus 629 was also 50% higher than for the diet with the untreated jojoba meal. This clearly shows that jojoba meal can be modified to improve its palatability. It is not clear, however, how this treatment affects acceptability of the meal.

Early studies (Booth, 1974) suggested that the simmondsin compounds found in jojoba meal were responsible for its detrimental effects on animal health and performance and this microbiological treatment method was selected for its efficacy in reducing the content of these compounds (Verbiscar, 1975). Although the meal used in these studies was not considered to be optimally treated (Verbiscar, personal communication, 1979), the L. acidophilus fermentation did reduce simmondsin from 4.20 to .50% and simmondsin-2'-ferrulate from 1.3 to .43%. The improved acceptability of the treated meal may have been due to its lower content of these compounds, but it seems unlikely that all of the improvement was due to this factor. For ruminants, it would appear that the appetite depressing factor may not be simmondsin.

Simmondsin and related compounds do not apparently have the same toxic effects on ruminant animals that they do on non-ruminants. Four steers were fed the diet contain-

ing 10% of the untreated meal for over 60 days with no deaths or detrimental effects other than those which would be consistent with the depressed feed intake. Furthermore, there was a gradual increase in consumption of this diet, indicating an adaptation to the appetite depressing factors. If simmondsin were toxic, in the usual sense of the word, prolonged exposure to the compound would be expected to increase the occurrence or severity of detrimental effects. When the untreated jojoba meal diet was discontinued, feed intake increased immediately and animal condition improved accordingly.

Although treatment of jojoba meal by L. acidophilus 629 improved palatability of the meal, it appeared to decrease the digestibility of nitrogen and other nutrient fractions. Digestibility of these fractions was lower in the treated meal diet, but not in the untreated meal diet, compared with the control diet containing cottonseed meal. It is quite possible that this effect is not inherent in the fermentation process but rather was due to the manner in which meal was handled after the microbial treatment. Treated meal which contained in excess of 35% moisture was dried at 75 C, conditions which would favor a Maillard reaction between amino and carbonyl groups in the meal (Feeney, Blankenhorn and Dixon, 1975). It is well established

(Carpenter, 1973) that this type of reaction is involved in "heat damage" of protein and decreases its availability to ruminants. Additional research would be needed to examine this question.

This study has shown that it is possible to at least partly overcome the appetite depressing factors found in jojoba meal. It is also apparent that the method used to treat jojoba meal for this study needs to be refined before it can be considered as a potential commercial process. Additional research is indicated to clarify whether ot not simmondsin and its related compounds are the major anti-nutritional factors in jojoba meal.

CONCLUSIONS

From the results of these experimental trials reported in this thesis, and the information available in the literature, the following conclusions were drawn.

1. The primary problem with jojoba meal as a potential feed ingredient for ruminants is its depressing effect on feed intake.
2. When given a choice of diets, both lambs and steers were able to select against diets containing untreated jojoba meal and lambs were more discriminatint in this regard than steers.
3. The low intake is probably due to a sensory factor yet to be identified.
4. Jojoba meal is probably not toxic to ruminants.
5. Treatment of jojoba meal with Lactobacillus acidophilus 629 improved its palatability for beef cattle.
6. Alternative methods for improving the nutritional value of jojoba meal need to be investigated.
7. Untreated jojoba meal might be effectively used as a range supplement component.

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