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Sheep Production for Weight Gain and wool with Unconventional Feed Sources

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Abstract: *The lack of traditional grazing land is a critical challenge for livestock rearing globally. Alternative botanical resources that can serve as fodder as therefore essential. In the highlands of the Chiapas State, Mexico, Cassia grandis offers potential for increasing weight gain and wool production in sheep. This study evaluates the benefits associated with inclusion of C. Grandis into sheep feeding. The results indicate that all rates of inclusion of C. Grandis resulted in weight gain, fleece quality and wool growth. In addition, an economic analysis of costs and benefits suggests that all treatments are profitable. The findings provide the rationale for including non-traditional feeding into sheep fodder in the Chiapas region to overcome the challenge of limited grazing resources. It is concluded that the inclusion of 10 % dried, ground Cassia grandis pods in the diet of growing lambs could have a favorable impact on the different productive parameters, both those related to body weight and fleece quality, and also the economic indicators (benefit-cost ratio).*

I. Introduction

Sheep rearing is a major livelihood activity for the Tzotzil ethnic group which inhabits the Chiapas highlands. As reported by Perezgrovas (2000), wool has a significant impact on family income contributing up to 36 % of household income through the sale of greasy or raw sheep wool in local markets, handicrafts, live sheep and manure for use as fertilizer in crops. The sale of greasy wool constitutes an important source of income, as the price of the fleeces, especially those that are black with long, thick fibers, is very high in local markets.The main limitations for sheep rearing in the region include overgrazing, dependence on environmental conditions for animal feeding, the high cost of balanced feed, and low use of existing feed resources in agroforestry systems, and low weight gain and growth in lambs (cf. Nahed, *et al*., 2003). Winter frosts cause native grasslands to dry out and the legumes to have no foliage, a situation that continues throughout the dry season (December-May). This is the most critical season in terms of animal nutrition and any food scarcity can translate to limited wool and milk production (Perezgrovas, 2004). To address this challenge, communities have explored non-native botanical resources with potential for use in animal feeding. Among them is the tree legume known as 'cañadonga' (*Cassia grandis*), a species that is found throughout the region and especially in reserves and agroforestry systems (Vera and Dorantes, 2006).Against this background, the objective of this study was to evaluate weight gain, wool production and quality and the profitability (cost-benefit analysis) of incorporating different levels of dried, ground *C. grandis* pods in lamb diets.

II. Materials and methods

Location

The research was conducted in the Chapias highlands region, at the facilities of the Centro Ovino Teopisca (CUITT), Universidad Autónoma de Chiapas. The Center is located in the municipality of Teopisca, at 16° 32’ 24” North latitude and 92° 28’ 19” West longitude, at an altitude of 1760 m, having a mean annual temperature of 16.6 °C. This region has a subhumid temperate climate with summer rains and a winter dry season (Gobierno del Estado de Chiapas, 1994).

Palatability test

Prior to the trial involving inclusion levels, 48 Chiapas breed lambs were used. Their diet consisted of grazing on native grass supplemented with ground corn stover-soybean meal, with 12.5 % CP, and they were dewormed on a monthly basis by rotating a wide range of commercial products. During the ‘cafeteria test’ the preference the lambs showed when offered the dried, ground pods of nine tropical legumes, namely *Albizia lebbeck, Prosopis juliflora, Enterolobium cyclocarpum, Senna atomaria*, *Acacia farnesiana*, *Cassia fistula, Guazuma ulmifolia, Acacia milleriana* and *Cassia grandis*, was assessed. The palatability or 'cafeteria test’ is a reliable tool to measure the levels of acceptance by sheep towards the use of new feed resources in the form of legume pods. The legumes were collected during the dry season (March-April) around Tuxtla Gutiérrez, the capital of the State of Chiapas; they were subsequently identified and dried in the shade for 4 weeks, after which

they were ground in a ball mill (4 mm particle size).The preference test was tested using two trials: (a) 100 % dried ground pods, and (b) 50 % pods in a mixture with 50 % ground corn straw. The test consisted of randomly selecting a group of 3 to 6 animals, which were introduced to a pen in which the pod samples had been placed. At the same time, 3 people recorded the behavior of 1 to 2 of these sheep for a period of 4 minutes, after which the animals were removed; 6 replications were performed for each of the 2 modalities (pods alone and pods with straw). The following behaviors and actions were assessed: 1) approaching the basin, 2) smelling the content, 3) tasting the food, and 4) eating it. During these two trials (pods alone and pods with straw), the preference of the animals for the *A.milleriana* pods was clear, so it was decided to have a third session in which this species was removed, leaving the other eight in mixtures with corn straw. The same methodology was followed with another batch of 24 sheep, again performing six replications.

Toxicity test

For the challenge (toxicity) test, four disposal Chiapas breed sheep were fed. Each one remained in a covered 1 x 3 m pen, equipped with a wooden canoe to place the supplement. The trial was conducted in the dry season to ensure no additional grazing.The animals were subjected to a feeding regime in which gradually increasing amounts of ground *C. grandis* pods were added to the basic diet of ground corn straw. The initial proportion of ground pod was 5 %, and this amount was doubled every 3 days until reaching 100 % inclusion. The trial lasted 18 days. The mixtures were provided on an *ad libitum* basis, estimating a daily intake of 350 g dry product, but adjusting the amount allowed waste to not exceed 10% as described by Peralta (2004).The toxicity assessment was carried out daily through clinical indicators, in addition to the valuation of the normal behavior for this species and breed. Taking into account feed indicators such as voluntary intake, the feed was provided on an *ad libitum* basis at 9:00 a.m., after collecting the leftover feed from the previous day and recording daily intake.

Animals

Forty 4-month-old lambs in five batches of eight randomly-allocated animals (4 females and 4 males) were used. The experimental unit consisted of 2 same-sex lambs housed in a 1 x 3.5 m pen. Each batch received a different inclusion level (0, 5, 10, 20 and 40 %) of dried, ground *Cassia grandis* pods mixed with a basic diet (79.5 % corn stover with cob, 13.0 % soybean meal, 5.0 % bran and 2.5 % mineral salts; 13 % CP).

The treatments (T_1, T_2, T_3, T_4 and T_5, respectively) were not formulated in an isoproteinic manner, because in this way the weight gain and fat retention may be different for each of the treatments (Di Marco, 1994).

The lambs received an initial ration of 400 g per experimental unit, as described in the methodology practiced by Velázquez (2005), making daily adjustments to avoid waste (Peralta *et al*., 2004.); final consumption was 1650 g per experimental unit. After a one-week adaptation period, the trial lasted 146 days. The housing was permanent, with free access to water within the pens. The animals were dewormed every month, rotating a broad spectrum of commercial products.Body mass was evaluated as a variable, by tracking the growth of each lamb and by batch, considering the weight gain every 15 days, from which the total gain in 146 days was calculated. Another productive indicator was the weight of the raw fleece at shearing, which was performed on day 75. Fleece weight was recorded *in situ*. Through laboratory analysis with the methodology proposed by Rojas (2003), yield after alcohol-based degreasing was calculated, whereas efficiency (wool growth per unit area) was calculated for two periods, the first 6 weeks after shearing and the second 7 weeks after the first determination.

Benefit/cost ratio:

The sum total of the benefits from the sale of wool (average price at which it is sold in the regional market, $250.00 per kg) and live sheep ($ 14.00 kg, average price in the regional market) were obtained. For methodological and calculation purposes, corn straw was assigned a cost of $ 1.00 despite being produced in the same place, the Centro Ovino Teopisca. The value of the medicines, facilities and labor involved in handling the animals was assumed to be a fixed cost. Data were processed using spreadsheets and the Minitab package for Windows version 3.1 for analysis of variance.

III. Results and discussion

Palatability test: The behavior of the sheep in terms of "approaching" and "smelling" the feed did not show significant differences in the 9 types of pods. For the "trying" behavior, a significant preference towards the *A. milleriana* pods was shown. Similarly, in the case of “eating” behavior, a significant preference for the *A. milleriana* pods over the other species was observed.

From the results of the trials, three large preference groups were identified (Figure 1). The first one includes the most sought-after and consumed pods, which were those of *A. milleriana*, *A. lebbeck* and *C. fistula*, whereas the

second most preferred group includes *E. cyclocarpum, G. ulmifolia* and *S. atomaria* pods and third included the least favored pods, which were those of *A. farnesiana*, *C. grandis* and *P. juliflora*.

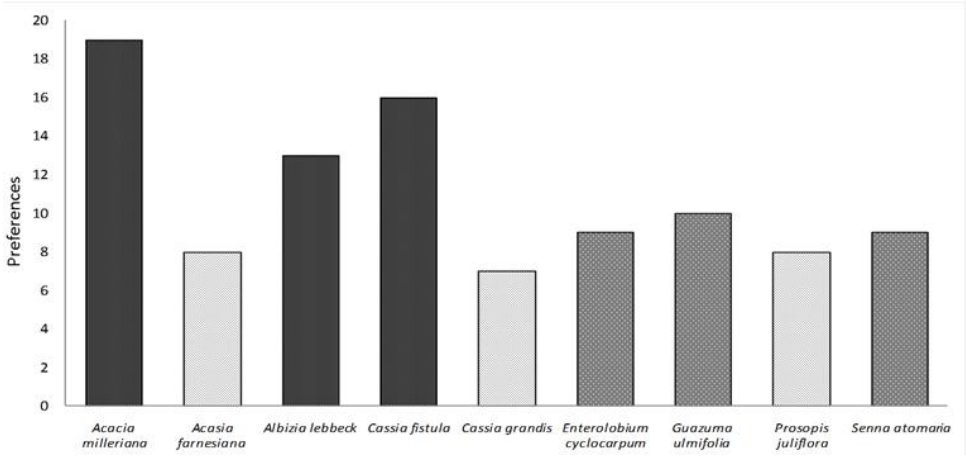

Figure1. Preference groups of sheep for pods alone or mixed with straw.

In the present study, the groupings were made simply according to the frequency with which the animals tried and consumed the different pods; the formation of the groups is not associated with the amount of condensed tannins found in the 9 forage pods (Table 2).

Table 2. Compositional analysis of the 9 ground forage pods

Sample	**Crude protein %**	**Kilocalories g^{-1}**	**Cond. tannins mg g^{-1}**
Senna atomaria	9.82	4.55	0.10
Guazuma ulmifolia	6.86	5.03	0.29
Prosopis juliflora	13.48	4.68	0.47
Albizia lebbeck	16.98	4.78	0.74
Acacia farnesiana	15.73	4.52	4.32
Enterolobium cyclocarpum	18.52	4.76	5.04
Cassia grandis	8.27	4.60	16.24
Acacia milleriana	10.33	4.11	16.42
Cassia fistula	7.99	4.77	27.39

During the cafeteria test, voluntary intake by each of the lambs that approached the different pails was not assessed, due to the limitation in terms of the feed resource. After a few minutes of consuming the feed, the animals were removed and the next group was assessed; however, the validity of this test is not questionable because a sufficient period of time was given to demonstrate that the animals preferred the consumption of certain pods.Animal acceptance of feed depends on several factors, one of which is the content of anti-nutritional factors due to their astringent effect. In the case of some large pods, such as those of *Cassia grandis*, the higher proportion of shell (and thus more fiber) compared to pulp or fruit (high in carbohydrates and sugars in the mucilage) is one of the factors that help explain their low palatability under the conditions of this test. By contrast, the use of cañadonga pods is justified by the lower collection cost, since their large size facilitates collection. heep present a high variability in intake, a situation that expresses the individuality of each one; in addition, sheep are food neophobic animals (rejection on the part of an animal to a new food), and need time to adapt intake to changes in diet. Despite this situation, carrying out the cafeteria test is considered appropriate and the results obtained are valuable within the comprehensive evaluation of the use of non-conventional feed resources.

***Toxicity test*:** The results obtained during the challenge test are presented in Figure 2, which shows there were no significant differences in terms of the intake of increasing portions (5, 10, 20, 40, 60 and 100 %) of ground *C.grandis* pods for the 4 sheep subjected to this test.

Voluntary intake increased gradually until the time when the animals were fed 100 % ground *C. grandis* pods, decreasing by up to 82.22 % (from 900 g to 160 g of feed consumed by sheep), but the sheep did not show any clinical signs of intoxication and their behavior was normal for the species. From the time when the animals were offered a diet with 100 % pods, a clear trend cannot be seen in the figure to establish that after a certain period of adaptation the sheep could reach the intake levels recorded with the initial proportions of *C. grandis*.

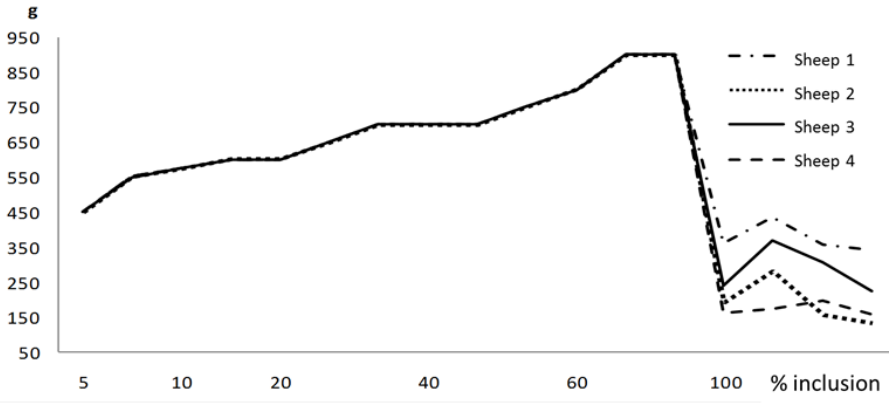

Figure 2. Line representing voluntary sheep intake during the challenge test for ground *C.grandis* pods.

Studies by Hervás (2001) on the effect of condensed tannins from different doses of the tree *Shinopsis lorentzii* (0, 0.5, 1.5 and 3 g/kg BW/d) on sheep nutrition and by measuring its intoxication effect showed that the dose of 3 g of *Shinopsis lorentzii* /kg BW, quickly reduced voluntary intake from the sixth day via ruminal administration, with commensurate loss of body weight. Stool consistency changed, becoming pasty and later evolving into diarrhea, while in those sheep subjected to doses of 0.5 and 1.5 g of Shinopsis lorentzii /kg BW the stools were only covered with abundant mucus.

The results in the present study are similar to those of Hervás (2001), since in 100% inclusion levels of ground *Cassia grandis* pods, voluntary intake decreased dramatically by up to 80 %. And likewise when the sheep received 100 % *C. grandis* pods, a change occurred in stool consistency, becoming pastier and turning to a dark brown color similar to the color of the ground pods.

Inclusion levels: The productive variables are presented in Table 3, where the means and standard deviations of the main variables studied for the different inclusion levels of *C. grandis* pods are shown. There were no significant differences among the different treatments. The trends indicated that the inclusion of 5 to 20 % pods favors the body weight indicators, whereas 10 % inclusion is associated with wool production (>0.05).

Table 3. Variables evaluated with different inclusion levels of *C. grandis*.

Variable	Mean ± SD
Initial weight, kg	20.52 ± 3.09
Final weight, kg	37.42 ± 5.38
Total gain, kg	16.90 ± 4.52
Fleece quality (1-4)	3.6 ± 0.4
Raw fleece weight, g	370 ± 91
Staple length, cm	10.65 ± 1.56
Wool efficiency, mg cm^2	0.356 ± 0.083
Total consumption, kg	152.1 ± 21.6

The results differ from those found by Velázquez (2005) also tested in Chiapas lambs, but using different inclusion levels of *A. farnesiana*, in whose trials a significant effect was reported on wool production characteristics with the inclusion of 20 % pods. This may be associated with the higher protein content of these pods compared with those of *C. grandis* (12.5 *vs*. 9.0 % CP).It was observed that the body weight gain during biweekly periods for each treatment begins segregating from the 5^{th} biweekly period, which was when the shearing was performed. The treatment with 5 % inclusion of *C. grandis* (T_2) tended to show greater weight gains during the experimental period.

After shearing, a decrease in weight gain was observed (Figure 3) due to the handling to which the animals were subjected and due to the removal of wool. The weight recovery period ranged from 1-2 fortnights, being slower in T_5. Weight gain after 146 days, per experimental unit, was from 15.0 kg for the treatment with 40 % inclusion of pods to 18.38 kg for T_2 (5 % *C. grandis* pods). There were no significant differences (>0.05) for weight gain at the different inclusion levels; however, a positive trend can be seen with 5 % inclusion (T_2), just as the treatment with 10 % inclusion (T_3) shows a trend to greater weight gain.

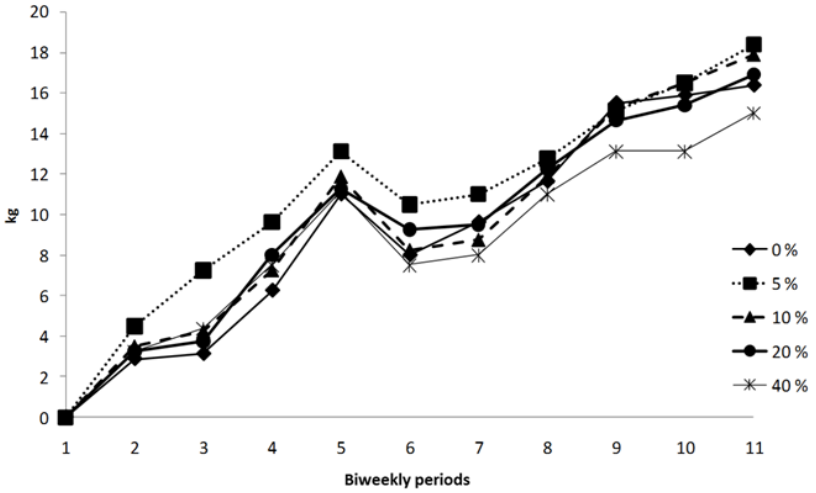

Figure 3. Body weight gain during biweekly periods in sheep fed with different inclusion levels of ground *C. grandis* pods.

The results differ from those found by Velázquez (2005) in Chiapas lambs during the dry season, using different inclusion levels of *Acacia farnesiana*, reporting a significant effect on the characteristics of wool production with the inclusion of 10 % pods. The differences may be associated with the higher protein content of *A. farnesiana* pods compared with those of *Cassia grandis* (12.5 *vs*. 8.27 % CP).

***Total body weight gain*:** Table 4 shows that after the lambs were subjected to different inclusion levels of *C. grandis*, the lambs that received 40 % pod inclusion (T_4) had a lower weight gain (15.0 ± 2.68 kg); however, no significant differences in total body weight gain were observed (>0.05).

Table 1. Total weight gain with different inclusion levels of *C.grandis*.

Percentage of *Cassia grandis* inclusion	Weight gain (kg)	±	SD
T_1: 0 %	16.38	±	4.77
T_2: 5 %	18.38	±	5.89
T_3: 10 %	17.88	±	5.81
T_4: 20 %	16.88	±	4.64
T_5: 40 %	15.00	±	2.68

Velázquez (2005) found that Chiapas lambs supplemented with inclusion of *A. farnesiana*, for 110 days, had total weight gains ranging from 13.6 ± 2.3 for the treatment without inclusion of this forage legume (*A. farnesiana*) to 15.25 ± 2.5 for the treatment with 10 % inclusion; no significant differences were found between each one (<0.05).

The results obtained in the present study differ from those found by Velázquez (2005) and can be attributed to the fact the trial period was longer and the differences in the protein content of each of the pods..

Wool production: In the case of raw fleece weight at shearing, no significant differences (>0.05) were observed; however, there was a higher gain (405 g) in lambs receiving 10 % inclusion of *C. grandis*, while the lower gain for raw fleece weight (330 g) corresponds to the lambs fed 20 % *C. grandis*.

The results during this evaluation period were found within the results obtained (337 ± 61 g for the treatment with 40 % inclusion to 388 ± 73 g) for the dry season by Velázquez (2005), because like the present study the evaluations were made during the dry season and the evaluated animals were of the Chiapas breed.

The difference in terms of the production of raw fleece depends on the cutting season, with production being higher in the autumn than in the spring. The seasonal influence is also significantly expressed in other productive parameters, such as wool growth per unit area, and the length and diameter of the fibers.

The yield at washing during the two assessment periods showed no significant differences (>0.05), the results being very similar for each of the periods without showing a trend toward any treatment.

High yield values at washing have a positive impact on the economy of indigenous weavers because a larger amount of raw textile material is generated when degreasing the wool of Chiapas breed lambs, which produce high quality wool for Tzotzil weavers.

The rate of wool growth during the first period tends to be higher in lambs fed with 5 % ground *C. grandis* pods (0.44 mg/cm^2/day) and conversely lower growth occurs in lambs fed with 40 % pods (0.28 mg/cm^2/day). For the

second period, a trend is not observed since the results are very similar; for both periods no significant differences (>0.05) were found.

The proportion of the different types of fibers is shown in Figure 4. It can be seen that the proportion of kemp fibers (undesirable for Tzotzil weavers) are smaller for the treatments with 10 and 20 % inclusion of *C. grandis*, while the treatment with 5 % inclusion was the one with the highest proportion of these fibers (7.7 %); however, there were no statistically significant differences among the treatments (>0.05). For the proportion of long fibers, there is a slight difference for the treatment with 10 % inclusion, with a proportion of 27.15 %; the lowest proportion of long fibers corresponds to the treatment with 0 % inclusion, with 23.2 %. For short fibers, which are found in greater proportion, the results do not show a trend toward any treatment, showing no statistically significant differences (> 0.05).

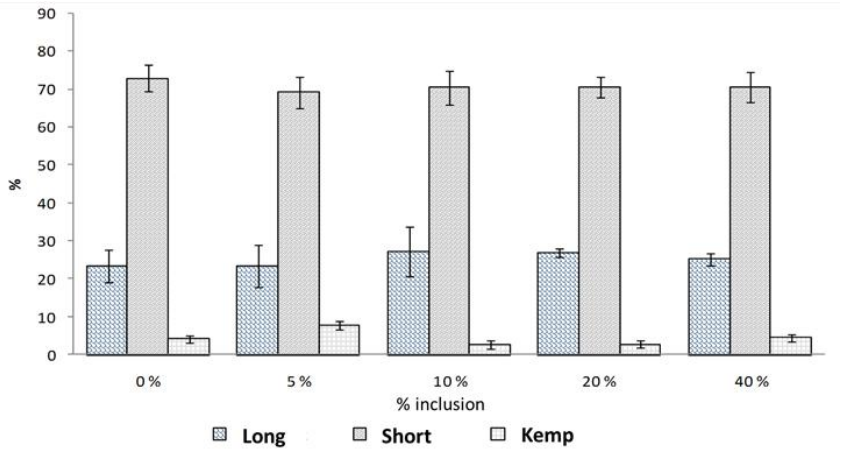

Figure 4. Relative proportion of the different fibers in the staple of lambs fed with different inclusion levels of *C. grandis* pods.

In the results for the evaluation of wool quality for the 5 treatments used, similarity was found in the ratings received by the animals of each of the treatments, without showing any trend indicating that one of them can have an influence on improving quality. No significant differences (>0.05) were found; the average quality for all the animals subjected to the different treatments is 3.6 ± 0.46, with 4 being the highest quality value.

It is believed that changes in fiber production and growth characteristics are associated with forage availability, which in turn depends on temperature and humidity conditions. There is a marked seasonal effect on the characteristics associated with wool production (g/biannual shearing) and fiber growth (mg cm^2 day^{-1}) in the Chiapas sheep, with significant increases in the rainy season and a decrease in the dry one (Perezgrovas *et al*., 1997).

Benefit/cost ratio: The diets included in this trial have a benefit/cost ratio higher than 2.0, indicating that benefits are greater than costs – often twice as beneficial. Table 5 shows that the control treatment has the lowest ratio, while the diet that included 40 % *C. grandis* pods obtained the optimum benefit.

Table 5. Benefit/cost ratio of groups of lambs fed different inclusion levels of ground "cañadonga" (*C. grandis*) pods.

Treatment	Benefits	Costs	B/C ratio
T_1: 0 %	2911.0	1341.39	2.17
T_2: 5 %	2964.5	1304.48	2.27
T_3: 10 %	2966.0	1276.80	2.32
T_4: 20 %	2739.0	1215.82	2.25
T_5: 40 %	2601.0	1087.57	2.39

These results are mainly associated with the low cost of cutting and transporting these pods, which due to their large size facilitates their collection and handling; by increasing the proportion of pods, the production cost decreases proportionally, while in the control treatment the greater quantity of soybean meal that must be included in the ration causes a cost increase. As a result, the relative protein content in the diets can be decreased by adding ground *Cassia grandis* pods, but are economical for keeping animals.

The benefit/cost ratio was also not proportional to the inclusion percentage of *Acacia milleriana* during the study by Velázquez (2005) with Chiapas breed lambs for 110 days (dry season), in which they were supplied different inclusion levels (0, 10, 20 and 40%) of ground pods of this forage legume in a base diet made from corn stover; in this experimental work the crude protein contents were 5.92 , 6.71 , 7.31 and 7.02 % for each of

the treatments respectively. The results of this trial showed that the relationship between the pod inclusion percentage and the economic indicator (benefit/cost) is not proportional because the lambs which received the 10 % pod inclusion percentage were those that had a higher benefit/cost ratio (3.97), followed by those that received 20 %; those that had a lower ratio were those subjected to 40 % inclusion of ground pods.

This trend is not observed in the present study because there were no significant differences (>0.05) in regard to feed consumption among the different treatments; however, the benefit/cost ratio of the treatment with 40 % inclusion attained the highest economic benefit ratio by having a greater inclusion percentage of the non-conventional protein source ('cañadonga'), which is easily accessible and has low collection and handling costs.
The use of alternate low-cost protein sources that are easily accessible in the region and have little or no competition, as is the case with *C. grandis*, thus have great potential to generate increased earnings from the sale of live animals and wool under the sheep rearing practices used in Tzotzil communities.

IV. Conclusions

The palatability or 'cafeteria test' is a reliable tool to measure the levels of acceptance by sheep towards the use of new feed resources in the form of legume pods. The results with regard to intake by the sheep depend on several factors including the amount of anti-nutritional factors contained, the fiber-carbohydrate ratio and if the animals were subjected to an adaptation period, among others.The dried, ground pods of *C. grandis* are not toxic up to 100 % inclusion, and the Chiapas breed lambs maintain normal behavior characteristic of the species, and without showing any clinical signs of intoxication; however, voluntary intake decreases by up to 80 % with 100 % pod inclusion.

Voluntary intake of ground *C. grandis* pods by Chiapas lambs is not statistically different (>0.05) among the different treatments (0, 5, 10, 20 and 40 %), and scientific evidence is generated in the sense that up to 40 % pod inclusion in the diet of lambs does not affect feed intake.
On lamb growth, reflected in weight gain, dried, ground *C. grandis* pods do not have a statistically significant effect (>0.05), although there is a tendency for the inclusion of between 5-10 % pods on a diet based on corn stover and ground corn to generate greater weight gain in animals.

There are no significant differences in total weight gains per experimental unit among the treatments; however, it can be seen that it tends to be higher in the lambs that received 40 % inclusion of dried, ground pods in the diet. Raw fleece production was not affected in a statistically significantly manner by the inclusion of pods; however, there was a tendency for greater wool production in lambs fed with 10 % inclusion. Inclusion of *C. grandis* pods has neither a positive or negative impact on some wool quality parameters, such as yield after alcohol-based degreasing and daily fiber growth per unit area (efficiency), but there is a tendency for 5 and 10 % inclusion of *C. grandis* pods in the diets for sheep to have increased weight gain and efficiency in the wool growth rate.

Regarding wool quality indicators, such as the quality rating of the fleece according to Tzotzil shepherds, staple length and the proportion of the different types of fiber, there are no significant differences due to the inclusion of *C. grandis* pods in diets for Chiapas breed sheep; however, there is a tendency for 10 % pod inclusion to have a positive impact on the length and proportion of desirable fibers for Tzotzil weavers.
All treatments including *C. grandis* pods showed a benefit/cost ratio greater than one, with the 40 % inclusion treatment having the highest benefit/cost ratio. The decrease in feed costs by using *C. grandis* pods as an alternative source of protein can have a positive impact by generating more income from the sale of good quality wool.Inclusion of 10 % dried, ground *Cassia grandis* pods in a base diet made from agricultural by-products such as corn straw may have a positive impact by increasing body development indicators as well as those of wool production and growth in lambs. Producer income from the sale of live animals and good quality wool increases because the benefit-cost ratio is higher compared to the inclusion of 5, 20 and 40 % *C. grandis* pods in the diet.

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