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Effect of Feeding *Prosopis juliflora* Pods and Leaves on Performance and Carcass Characteristics of Afar Sheep

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ABSTRACT

Twenty Afar male sheep with initial mean body weight ± SD of 17.87 ± 1.19 kg were used to evaluate the effect of replacing commercial feed with *Prosopis juliflora* pods and leaves on growth performance, carcass and meat quality characteristics. Animals were equally divided into four dietary treatment groups for 120 d (Rhode grass hay (RGH), RGH + 300 g ground *P. juliflora* pods (PJP), RGH + 150 g each ground *P. juliflora* pods and leaves mix (PJPLM) and RGH + 300 g commercial concentrate mix (CCM) per head per day). Total dry matter and crude protein intakes increased ($P < 0.05$) in treatments supplemented with ground PJP and CCM. The average weight gain and meat quality parameters obtained by supplementing with 300 g ground PJP were significantly higher than the RGH and PJPLM treatment groups, but were comparable with that of CCM. The present study demonstrated the potential of using PJP for Afar lambs without adverse effects on growth and carcass characteristics. However, the intake of PJP reduced when mixed with leaves and this indicates the leaves are unpalatable.

Keywords: *Prosopis juliflora*, Afar sheep, growth, feed intake, carcass characteristics

INTRODUCTION

Low quality and inadequacy of feeds as well as malnutrition are considered to be the major constraints hampering productivity of livestock in Ethiopia. The growth rate of animals fluctuates because of the seasonality of forage availability. To minimize the impact of fluctuations in seasonal feed availability, supplementation of concentrates is known to improve intake and digestibility of roughages (Nurfeta, 2010). However, the use of such supplements is limited under pastoral livestock production systems due to the scarcity and high cost of concentrates. In order to mitigate the problems associated with the lack of feed supplement, there is a need to look for alternative protein sources that pastoralists can produce in their own locality. Accordingly, trees and shrubs are the prominent sources of forage for range ruminants and have not been fully utilized due to scant research information regarding their potential as livestock feed in arid and semi arid areas (Koech *et al.*, 2010).

Prosopis juliflora is one of the rangeland trees that can grow in a wide range of soil and climatic conditions. It is a genus of trees and shrubs in the legume family (*Leguminosae*, subfamily *Mimosoideae*), native to arid and semi-arid regions

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of the Americas (Pasiecznik *et al.*, 2001). The plant was introduced to Ethiopia in the 1970s. Over the years, *P. juliflora* has spread outside the designated plantation areas, adversely affecting natural habitats, rangelands and cultivated areas in many parts of the country. In contrast to its undesirable effects as an invasive weed, *P. juliflora* is a valuable multipurpose resource that provides timber, firewood, livestock feed, human food, shade, shelter and soil improvement (Pasiecznik *et al.,* 2001).

P. juliflora trees generally commence fruiting in the second year after planting in Brazil (Silva, 1990) and in Kenya (Otsamo and Maua, 1993). There are generally one or two main fruiting periods. However, in some regions, flowering and fruiting are continuous (Goel and Behl, 1996; Pasiecznik *et al*., 2001). Some old trees in India produced up to 100 kg of pods per tree per year, while the average for adult trees is considered 40 kg per tree per year. The pods of *P. juliflora* are rich in crude protein (CP), minerals and amino acids (Pasiecznik *et al*., 2001). The results of feeding trials indicate that rations for goats, sheep, beef cattle and dairy cattle can give very good weight gains or milk production or both when about 60% of the diet consists of ground *Prosopis* pods (Abdullah and Abdel Hafes, 2004).

The leaves of *P. juliflora* have high CP (20%) and a low level of fibers (Anttila *et al.*, 1993). While generally unpalatable due to the presence of tannins, flavonoids and polyphenols (Cameron *et al.*, 1988), livestock are known to occasionally browse dry foliage due to the denaturation or removal of unpalatable compounds during drying (Pasiecznik *et al*., 2001). In India, Shukla *et al. (*1984) reported the possibility of incorporating *P. juliflora* foliage in the diet of small ruminants though the animals reduced intake at levels above 10% of the total ration. Since there has been a lack of indigenous knowledge of *P. juliflora* management in the Afar region of Ethiopia, this species has remained under-utilized and unmanaged. Scientific information is lacking on the feeding value of *P. juliflora* pods and leaves in relation to Afar sheep performance and the communities have not been advised on the management practices to fully exploit *P. juliflora* plants that have invaded their rangelands. Therefore, the aim of this study was to evaluate the supplementary value of feeding *P. juliflora* pods and leaves to sheep fed a basal diet of Rhodes grass (*Chloris gayana*) hay.

MATERIALS AND METHODS

Location of study area and experimental feeds

The experiment was conducted at the Werer Agricultural Research Center (WARC) located in Amibara Wereda, Gebi Zone of the Afar National Regional State, Ethiopia. The site is located at 9°10’S and 40°9’E, 270 km northeast of Addis Ababa, Ethiopia.

Rhodes grass (*Chloris gayana*) was grown at WARC and used as a basal diet by cutting at 30 d intervals. Supplemental feeds used for the study were ground *P. juliflora* pods (PJP), *P. juliflora* leaves (PJL) and a commercial concentrate mix (CCM) made up of cottonseed meal, wheat bran and salt. Pods and leaves were collected from *P. juliflora* trees grown in the study area. Fresh leaves were harvested from available trees regardless of tree age, and the leaves were trimmed from the twigs onto a plastic sheet. The trimmed leaves were then finally dried by spreading thinly on a plastic sheet under shade and turning regularly to ensure uniform drying for safe storage. The collected pods were sun dried, chopped to shorter lengths and further ground using a hammer mill (Wet Type Grinding Mill, manufactured by Selam VTC, Addis Ababa, Ethiopia).

Chemical analysis of experimental feed

The chemical analysis was carried out at the Debrezeit Agricultural Research Center. The partial dry matter (DM) concentration of feed and feed refusal was determined by drying in a forced-air oven at 60 ºC for 72 hr. The samples were then ground to pass through a 1-mm screen and stored in airtight polyethylene bags pending chemical analysis. Dry matter of the samples was determined by oven drying at 105 ºC for 24 hr and the ash content by igniting in a muffle furnace at 600 ºC for 6 hr. The nitrogen content was determined by the micro-Kjeldahl method and crude protein was calculated as N × 6.25 (AOAC, 1990). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined according to Van Soest *et al.* (1991).

Experimental animals, design and treatments

Twenty yearling, intact, male Afar sheep with mean body weight ± SD of 17.87 ± 1.19 kg were used for this experiment. The experimental animals were housed in individual pens with a concrete floor and each animal had separate feeding and watering troughs. The animals were adapted to the experimental conditions and feeds for 15 d, which was followed by 120 d of the feeding trial. The experimental treatments were Rhodes grass hay (RGH) *ad libitum* (T1); RGH *ad libitum* + 300 g ground *P. juliflora* pods (PJP) per head per day (T2); RGH *ad libitum* + 150 g each ground *P. juliflora* pods and leaves mix (PJPLM) per head per day (T3) and RGH *ad libitum* + 300 g commercial concentrate mix (CCM) per head per day (T4). Five sheep were randomly assigned to each of these four treatments in a completely randomized design. Supplementation of 300 g concentrate feed per head per day was applied based on the recommendations of Hagos and Melaku (2009) for a similar breed to the one used in this study and of Mulat *et al.* (2011) for Washera sheep.

The supplements were offered into two equal halves at 0800 and 1600 hours. RGH was offered for *ad libitum* intake. Hay and supplemental feeds were offered separately. All sheep had free access to clean water throughout the experimental period. The amounts of RGH and supplemental feed offered and refused were recorded daily to estimate the intake for each animal.

Animals were weighed every 14 d after overnight fasting using a suspended weighing scale. At the end of the experiment, all the experimental sheep were fasted for 12 hr, weighed and slaughtered at the facilities of Mojo Organic Export Abattoir, Ethiopia. Fasted live weight was recorded immediately before slaughtering, and hot carcass weight was recorded after slaughter. Cold carcass weight was recorded after chilling the carcass at 4 °C for 24 hr. The dressing percentage was calculated as the percentages of cold carcass weight to fasted live weight. Non-carcass edible components were removed and weighed directly after slaughter. The external and internal offal such as head + horn, skin + feet, testes + penis, kidneys, lungs + trachea, heart, liver and spleen were recorded. The empty body weight was calculated as the difference between the slaughter and gut contents. Edible offal components (lung + trachea, heart, liver, empty gut and kidneys) were measured separately. The leg length, carcass length, chest depth and thigh circumference were measured on the chilled carcass. Each carcass was split into two equal halves by cutting through the vertebral column. Both sides were weighed and the left side of each carcass was dissected into gross tissue components—lean meat, bone and carcass fat (subcutaneous and intramuscular)—for estimation of carcass composition. Following a 30-minute ‘bloom’ time, color was measured on meat slices of 15 mm thick. Commission Internationale de l’Eclairage (CIE) 1976 color space (L*, a* and b* values) were measured using a Hunter Mini Scan unit (Model XE Plus 45/0 LAV; Hunter Associates Laboratory Inc.; Reston, VA, USA) where L* depicts relative lightness, a* indicates relative redness and b* represents relative yellowness (Hunter and Harold, 1987).

Economic analysis was performed based on a comparison of feed costs. The current feed costs, calculated on a per kg DM basis, were 1, 0.50, 0.50 and 5.20 birr (USD 1 = 16.35 birr at time of publication) for RGH, PJP, PJPLM and

CCM, respectively. The profitability of feeding each experimental diet was estimated using the selling price of each experimental sheep at local market place. The difference between the sale and purchase price was considered as the total return in the analysis. The net return was calculated by deducting the total variable cost from the total return.

Statistical analysis

All the data on feed intake, body weight change and carcass parameters were analyzed using the general linear model (GLM) procedure of the Statistical Analysis System software package (SAS, 2010). Treatment means were separated using a least significance difference test. The model used for the analysis of growth, feed intake and carcass parameters is shown in Equation 1 (Steel and Torrie, 1980):

$$Y_{ij} = \mu + T_i + e_{ij} \quad (1)$$

where Y_{ij} is the response variable, μ is the overall mean, T_i is the treatment effect and e_{ij} is the random error.

RESULTS AND DISCUSSION

The chemical composition of feeds used in this experiment is shown in Table 1. The CP content of CCM was very high compared to the other feeds. Similarly, the CP content of PJL was high compared with RGH and PJP. The NDF and ADF contents of RGH were very high compared with the PJP and the leaves as well as CCM. The CP content of RGH used in this experiment was high compared to the result (8%) obtained by Mahgoub *et al.* (2005).

The RGH also had a CP content above the minimum microbial requirement (7%) in feeds to support acceptable ruminal microbial activity and the maintenance requirement of CP for the host ruminant (McDonald *et al.,* 2002), which necessitates supplementation. The CP content of PJP used in this study was comparable with the value (14% DM) reported by Mahgoub *et al.* (2005), but lower than the value (16.2% DM) obtained by Vimal and Tyagi (1986). The CP content of PJL used in the current study was higher than the values (20.3 and 18.5 % DM) reported by Cameron *et al.* (1988) and Singh *et al.* (1988), respectively. The variation among data in the literature could be due to the age of the leaves at harvest, the soil type and fertility as well as the agro-ecological system under which the trees were grown. According to Maasdorp *et al.* (1999), the plant species or variety, soil, climate, grazing, plant fraction and stage of maturity at sampling affect the nutritive value of forages.

The NDF content of PJP obtained in this study was lower than the values reported by Mahgoub *et al.* (2005) and Vimal and Tyagi (1986). Similarly, the ADF content of PJP was lower than the value (21%) reported by Mahgoub *et al.* (2005) but higher than the value (13.5%) obtained by Abdullah *et al.* (2011). Both the NDF and ADF contents of PJP were much lower than the values (51.8 and 29.8 %, respectively) reported by

Table 1 Chemical composition of the experimental feeds.

Feed type	DM (%)	CP (%)	NDF (%)	ADF (%)	ADL (%)	Ash (%)
RGH	90.9	12.2	63.0	38.9	3.8	9.6
PJP	89.7	14.9	29.8	17.0	4.2	5.3
PJL	92.3	21.6	27.1	18.2	3.2	8.7
PJPLM	91.4	18.3	28.3	17.5	3.6	7.1
CCM	91.8	25.8	28.2	14.8	4.9	7.9

DM = Dry matter; OM = Organic matter; CP = Crude protein; NDF = Neutral detergent fiber; ADF = Acid detergent fiber; ADL = Acid detergent lignin; RGH = Rhodes grass hay; PJP = *Prosopis juliflora* pods; PJL = *P. juliflora leaves*; PJPLM = *P. juliflora* pods and leaves mix; CCM = Commercial concentrate mix.

Koech *et al.* (2010). In general, the NDF contents of both PJP and PJL were very low, which has implications with regard to improving feed intake. On the other hand, the NDF and ADF contents of RGH were higher than the supplements and may have had an impact on intake and digestibility.

The total dry matter intake was higher (P < 0.05) for those sheep supplemented with ground PJP and CCM compared to animals fed RGH (Table 2). Although *P. juliflora* leaves were supplied by mixing with ground pods, the leaves were unpalatable to the extent that they significantly reduced the pod intake. The possible explanation for poor palatability is that *P. juliflora* leaves are known for their high tannin content of more than 5% (Simpson, 1977) and also contain 2.5 to 6.5 times as much phenolics compounds and other toxic components compared to alfalfa (Cameron *et al.*, 1988). Consequently, the hay dry matter intake of Afar sheep was significantly higher (P < 0.05) in the PJPLM treatment. Even though further research is needed to investigate the exact reason or reasons, many authors (Murro *et al.*, 2003; Takele and Getachew, 2011; Khan and Habib, 2012) have reported a significant increase in the DM intake associated with feed supplementation using legume tree leaves.

The results of the experiment showed a significant difference (P < 0.05) in the total DM intake among treatments. Accordingly, the total DM intake was higher (P < 0.05) in treatments supplemented with CCM and PJP than with either the PJPLM or the RGH diet groups. This result was in line with the results of other studies (Mahgoub *et al.*, 2005; Abdullah *et al.*, 2011). Similar to the results of the current study, Abdullah *et al.* (2011) observed an increase in the total DM intake with an increase in supplementation with PJP and sesame hulls. This could be attributed to the high proportion of the supplement in the total diet. The CP intake was different (P < 0.05) among treatment groups; it was significantly higher in the CCM treatments and PJP diets.

The mean final body weight and mean daily live body weight gain obtained in the present study were higher (P < 0.05) for treatments

Table 2 Mean feed intake and body weight change of Afar sheep fed Rhodes grass hay with different supplements.

Variable	T1	T2	T3	T4	Significance
Hay DM intake (g per head per day)	437.14^{b}	435.80^{b}	522.98^{a}	449.00^{ab}	*
Supplement DM intake (g per head per day)	0.00^{c}	282.55^{a}	47.82^{b}	285.71^{a}	***
Total DM intake (g per head per day)	437.16^{c}	718.35^{a}	570.80^{b}	734.71^{a}	***
Total DM intake (g per kilogram $W^{0.75}$ per day)	49.07^{c}	73.09^{a}	62.50^{b}	73.76^{a}	***
Crude protein intake (g per head per day)	53.33^{d}	93.19^{b}	68.27^{c}	156.31^{a}	***
Initial body weight (kg)	17.76^{a}	18.10^{a}	17.62^{a}	18.00^{a}	NS
Final body weight (kg)	19.28^{c}	24.16^{ab}	20.54^{bc}	25.00^{a}	***
Live weight change (kg)	1.52^{b}	6.06^{a}	2.92^{b}	7.00^{a}	***
Live weight gain (g per head per day)	12.67^{b}	50.50^{a}	24.00^{b}	55.83^{a}	***

Means in the same row with a different superscript ($^{a, b, c, d}$) are significantly different; * = (P < 0.05); *** = (P < 0.001); NS = Not significant.

supplemented with either ground PJP or CCM compared to the RGH and PJPLM treatments (Table 2). The significant body weight gain from sheep fed on the PJP and CCM treatments could be attributed to the higher total DM and CP intakes compared with those of RGH and PJPLM (Table 2). The grass hay intake was lower in the PJP treatment compared to CCM perhaps because the animals felt satisfied as a result of the high level of sugar in the pods (Batista *et al.*, 2002).

A study conducted by Foster *et al.* (2009) showed that legume supplementation of the basal diet of sheep fed grass hay improved the intake of DM and CP. Consistent with the current findings, a significant improvement in growth performance was reported in sheep supplemented with PJP (Mahgoub *et al.,* 2005). Moreover, Abdullah *et al.* (2011) observed increased body weight when the basal diet of elephant grass for Omani sheep was supplemented with PJP. The amount of PJP supplementation in the current study was similar to that reported by Abdullah *et al.* (2011) in sheep fed a basal diet of RGH supplemented with PJP and sesame hulls. Similarly, Abdullah and Abdel Hafes (2004) studied the effect of the inclusion of different levels of PJP in the diet of Awassi lambs and found that the final weight and average daily gain were not affected by the inclusion of PJP at different levels compared to CCM.

The weight gain results observed in this study were similar to the values reported by Hailu *et al.* (2011) for Wogera sheep fed on rice straw supplemented with graded levels of CCM. The results were also consistent with the value reported by Hagos and Melaku (2009) for Afar sheep fed grass hay basal diet supplemented with CCM. Contrary to the current results, Obeidat *et al.* (2008) reported a reduction in feed intake when diets had high levels of PJP. Ravikala *et al.* (1995) and Mahgoub *et al.* (2005) reported that the presence of trypsin inhibitor, tannins and other phenolic compounds found in the pods suppressed the appetite of animals to the diet. The reduction in feed intake might have be due to the use of PJP without grinding in these experiments. In general, the results of the current study revealed that feeding PJP could be a possible alternative to range animals enabling the realization of more weight gains without incurring additional costs to those involved in feeding RGH as well as CCM.

The average values of hot carcass weight and dressing percentage on a slaughter weight basis were significantly ($P < 0.05$) higher for PJP and CCM compared to RGH and PJPLM (Table 3). Similarly, the dressing percentage on an empty body weight basis was significantly ($P < 0.05$) higher for PJP compared to RGH and PJPLM. The mean slaughter weight and empty body weight of sheep supplemented with PJP were higher than those of RGH and PJPLM trestments (Table 3). The carcass characteristics results observed in the current study were similar to Obeidat *et al.* (2008) who reported lambs supplemented with PJP and barley grains had significantly higher hot carcass weights and dressing percentages than the non-supplemented lambs. The treatment groups supplemented with PJP and CCM were higher ($P < 0.05$) in most edible offal contents (Table 3). This result is in agreement with the results reported by Hailu *et al.* (2011) in Washera sheep where the supplemented treatments had higher total edible offal than the non supplemented ones.

The size of the heart, liver and kidneys were significantly ($P < 0.05$) affected due to supplementation (Table 3). The lowest weight of edible parts was recorded from the RGH treatment and the highest from the CCM and PJP supplementation; which implies that by increasing the nutritional densities of the diet, it was possible to obtain heavier carcasses (Alexandre *et al.*, 2010). Similarly, there was a significant difference ($P < 0.05$) in the weights of some non-edible offal due to CCM and PJP supplementation.

The most important results of carcass characteristics obtained in the current study were comparable with results reported by Obeidat *et al.* (2008) for Awassi lambs in Oman. The present results clearly indicate that Afar sheep with alternative feeds significantly increased carcass characteristics and edible parts or meat quality. The results of the current study are in agreement with the results reported by Hagos and Melaku (2009) for the same breed. Their report indicated that the supplementation of Afar rams with CCM promoted the feed intake, digestibility, body weight gain and carcass parameters.

The measurements of the meat quality characteristics of the Afar lambs are presented in Table 4. Significant differences were observed among treatment diets in chest depth and total lean meat. Significantly higher ($P < 0.05$) total lean meat and chest depth were obtained from those animals supplemented with CCM and PJP diets. On the other hand, the significantly lowest fat cuts of meat were measured from animals fed on RGH alone. The lean to fat ratio was higher ($P < 0.05$) for RGH treatments than PJP and PJPLM. There was no significant difference in chilled meat shrinkage among treatments. Similarly, supplementation with PJP and PJPLM as well as CCM diets did not show any significant impact on leg, chest and thigh length. The results of the current study are consistent with those reported by Abdullah and Abdel Hafes (2004) and Mahgoub *et al.* (2005). It is possible that feeding such diets results in changing the portioning and distribution of available nutrients in a way that provides more nutrients to edible parts of the carcass.

No differences were observed in brightness (L^*), redness (a^*) and yellowness (b^*) between all treatment diets. The meat quality parameters measured were comparable among all the treatment diets except for total fat percentage and lean meat which were more favorable in the PJP and CCM treatments compared to RGH and PJPLM.

Table 3 Carcass parameters, edible and non-edible carcass offal of growing lambs fed four different diets.

Parameter	T1	T2	T3	T4	Significance
Empty body weight (kg)	12.52^{b}	18.80^{a}	13.44^{b}	20.06^{a}	***
Hot carcass weight (kg)	5.96^{b}	10.28^{a}	6.52^{b}	10.52^{a}	***
DP on LW at slaughter	34.91^{b}	44.37^{a}	36.55^{b}	42.77^{a}	***
DP on EBW	47.51^{c}	54.77^{a}	48.30^{bc}	52.42^{ab}	***
Lung, trachea and esophagus (kg)	0.198^{b}	0.257^{a}	0.211^{b}	0.290^{a}	***
Heart (kg)	0.089^{bc}	0.109^{ab}	0.076^{c}	0.121^{a}	***
Liver with gallbladder (kg)	0.212^{b}	0.308^{a}	0.216^{b}	0.329^{a}	***
Empty gut (kg)	0.90^{a}	1.06^{a}	0.90^{a}	1.04^{a}	NS
Tongue (kg)	0.05^{a}	0.06^{a}	0.07^{a}	0.06^{a}	NS
Kidneys (kg)	0.071^{c}	0.147^{a}	0.098^{bc}	0.123^{ab}	***
Spleen and pancreas (kg)	0.035^{b}	0.048^{ab}	0.041^{ab}	0.056^{a}	*
Head (kg)	1.34^{b}	1.58^{a}	1.34^{b}	1.74^{a}	***
Skin (kg)	1.72^{b}	2.44^{a}	1.76^{b}	2.86^{a}	***
Testicles (kg)	0.271^{b}	0.388^{a}	0.276^{b}	0.415^{a}	***
Empty gut (kg)	0.86^{a}	1.06^{a}	0.90^{a}	1.04^{a}	NS
Feet (kg)	0.517^{bc}	0.590^{b}	0.512^{c}	0.671^{a}	***

T1 = Rhodes grass hay (RGH) *ad libitum*; T2 = RGH *ad libitum* + 300 g per head per day ground ground *P. juliflora* pods; T3 = RGH *ad libitum* + 150 g per head per day mix of ground *P. juliflora* pods and leaves; T4 = RGH *ad libitum* + 300 g per head per day commercial concentrate mix.

EBW= Empty body weight; DP= Dressing percentage; LW= Live weight.

Means in the same row with different superscript ($^{a, b, c}$) are significantly different; * = ($P < 0.05$); *** = ($P < 0.001$); NS = Not significant.

Table 4 Some meat quality characteristics of Afar lambs fed on RGH Rhodes grass hay with different supplements.

Characteristic	T1	T2	T3	T4	Significance
Chilled meat shrinkage (%)	0.28[a]	0.30[a]	0.18[a]	0.30[a]	NS
Leg 1 length (cm)	27.20[a]	28.40[a]	26.20[a]	27.80[a]	NS
Leg 2 length (cm)	26.40[a]	28.20[a]	26.40[a]	28.00[a]	NS
Chest length (cm)	58.60[a]	63.00[a]	61.20[a]	64.00[a]	NS
Chest depth (cm)	28.00[b]	33.20[a]	29.00[b]	35.60[a]	***
Thigh 1 length (cm)	25.80[a]	27.00[a]	25.40[a]	26.40[a]	NS
Thigh 2 length (cm)	26.20[a]	26.80[a]	25.20[a]	26.20[a]	NS
Total lean (kg)	1.68[bc]	2.24[b]	1.44[c]	2.88[a]	***
Total fat (kg)	0.26[c]	0.94[a]	0.46[bc]	0.74[ab]	*
Total bone (kg)	0.98[a]	1.24[a]	1.18[a]	1.26[a]	NS
Lean to fat ratio	7.32[a]	3.17[b]	3.10[b]	4.29[ab]	***
Lean to bone ratio	1.77[b]	1.89[ab]	1.22[c]	2.29[a]	***
Color coordinates					
*L** (brightness)	32.01[a]	30.59[a]	32.60[a]	30.77[a]	NS
*a** (redness)	9.13[a]	8.53[a]	8.89[a]	8.33[a]	NS
*b** (yellowness)	9.13[a]	8.85[a]	8.89[a]	8.33[a]	NS

T1 = Rhodes grass hay (RGH) *ad libitum*; T2 = RGH *ad libitum* + 300 g per head per day ground ground *P. juliflora* pods; T3 = RGH *ad libitum* + 150 g per head per day mix of ground *P. juliflora* pods and leaves; T4 = RGH *ad libitum* + 300 g per head per day commercial concentrate mix.
Means in the same row with different superscript ([a, b, c]) are significantly different; * = $P < 0.05$; *** = ($P < 0.001$); NS= Not significant.

The costs of feeding the experimental diets are summarized in Table 5. The use of PJP as a supplement diet for sheep significantly maximized the profit of the feedlot operation of Afar sheep compared to both CCM and RGH treatments. Using CCM was more expensive than the corresponding costs for the PJP-based diet. The costs in the PJP treatment were mainly the collection of pods, milling and transportation.

Ravikala *et al*. (1995) reported significantly lower feeding cost when PJP was included in lamb rations in India. The report indicated that inclusion of PJP lowered the feeding cost of rearing feedlot lambs to market weight. Different authors also reported the economic advantages of PJP supplementation for small ruminants (Obeidat *et al.*, 2008; Koech *et al.*, 2010; Abdullah *et al.*, 2011), cattle (Talpada *et al.*, 2002) and poultry (Yusuf *et al.*, 2008). In the present study, supplementation of PJP for Afar lambs doubled the net return compared with that of the RGH diet and increased by more than 70% the net return from the PJPLM and CCM diets. Though the net return from feeding CCM was less than the corresponding profit of PJPLM treatments, it is very important to acquire a standard weight in sheep destined for the export market of the country.

CONCLUSION

Results obtained from this study demonstrated that supplementation of the diet of Afar sheep with ground *P. juliflora* pods resulted in improved feed intake, growth performance and carcass parameters. The inclusion of ground pods is potentially valuable and can be considered as a cheap alternative feedstuff to replace commercial

Table 5 Cost of feeding experimental diets to Afar sheep.

Parameter	T1	T2	T3	T4
Number of animals	5	5	5	5
Purchase price of sheep (Birr[1] per head)	500	500	500	500
Total basal diet intake (kg per head per 120 d)	52.46	52.30	62.76	53.88
Total supplement intake (kg per head per 120 d)	0.00	33.91	5.72	34.28
Cost of basal diet (birr per /head)	52.46	52.30	62.76	53.88
Cost of supplemental feed (birr per head)	0.00	33.91	5.73	178.28
Total variable cost (birr per head)	52.46	86.20	68.50	232.16
Selling price of sheep (birr per head)	674.80	845.60	718.90	875.00
Total return (birr per head)	174.80	345.60	218.90	375.00
Net return (birr per head)	122.34	259.40	150.40	142.84

T1 = Rhodes grass hay (RGH) *ad libitum*; T2 = RGH *ad libitum* + 300 g per head per day ground ground *P. juliflora* pods; T3 = RGH *ad libitum* + 150 g per head per day mix of ground *P. juliflora* pods and leaves; T4 = RGH *ad libitum* + 300 g per head per day commercial concentrate mix.

[1] birr = Ethiopian currency (1 USD = 16.35 birr at time of publication).

concentrate mix. In addition to improving the feed value, the milling of the pods can be used as one of the mechanisms to control the invasion of the plant in the rangelands. However, it was concluded that the feed prepared from *P. juliflora* leaves is not palatable to use as a supplement feed for Afar sheep and further research is required to improve its utilization as animal feed.

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