Asian Journal of Research and Review in Agriculture

Volume 6, Issue 1, Page 391-398, 2024; Article no.AJRRA.1679

Economic Benefits of Supplementing Tsara (*Pterocarpus lucens*) and Pigeon Pea (*Cajanus cajan*) Leaves Relative to a Concentrate Mixture in Hay-based Diets for Begait Sheep in Tselemti District, Tigray, Ethiopia

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Author's contribution

The sole author designed, analysed, inteprted and prepared the manuscript.

Article Information

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://prh.globalpresshub.com/review-history/1679

Original Research Article

Received: 18/07/2024
Accepted: 22/09/2024
Published: 28/09/2024

ABSTRACT

The objective of the study was to determine if supplementing Tsara (*Pterocarpus lucens*) and Pigeon pea (*Cajanus cajan*) leaves would be more cost-effective compared to a concentrate mixture when fed to Begait sheep in the Tselemti District of the North Western zone of Tigray, Northern Ethiopia, alongside a basal diet of hay. The experiment involved twenty-five yearling male Begait sheep. Five dietary treatments were arranged in a randomized complete block design (RCBD): Tsara leaves alone (T2), Pigeon pea leaves alone (T3), a combination of Tsara and

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Cite as: *Teklehaymanot, Abraham. 2024. "Economic Benefits of Supplementing Tsara (Pterocarpus Lucens) and Pigeon Pea (Cajanus Cajan) Leaves Relative to a Concentrate Mixture in Hay-Based Diets for Begait Sheep in Tselemti District, Tigray, Ethiopia". Asian Journal of Research and Review in Agriculture 6 (1):391-98. https://jagriculture.com/index.php/AJRRA/article/view/114.*

Pigeon pea leaves (T4), and concentrate mixture (T5). The control group received only hay (T1). The study evaluated net income and marginal rate of return (MRR) of different feed supplementation strategies using partial budget analysis. Results from the partial budget analysis indicated that the supplementing with concentrate mixture (T5) yielded the highest net income per head, followed by Tsara leaves (T2), Pigeon pea leaves (T3), the combination of Tsara and Pigeon pea leaves (T4), and the non-supplemented group (T1). Specifically, the net income from the concentrate mixture was 1879.95 Ethiopian Birr (ETB), while Tsara leaves, Pigeon pea leaves, and the Tsara-Pigeon pea mixture generated 1541.50, 1183.60, and 1232.95 ETB, respectively. Hay alone resulted in a net income of 991.50 ETB. Furthermore, the study assessed the marginal rate of return (MRR), revealing that the concentrate mixture (109%), pigeon pea leaves (92%), and the Tsara-Pigeon pea leaves mixture (67%) had the highest MRRs, with Tsara leaves achieving the highest MRR of 110%. Based on the findings, it is recommended that sheep farmers in the Tselemti District consider supplementing with Tsara leaves and the concentrate mixture to achieve financially viable returns. In areas where access to concentrate mixture is limited, Pigeon pea leaves and a combination of Tsara and Pigeon pea leaves can serve as viable alternative feed sources. To validate these results and optimize the utilization of these feed resources in local settings, further studies and on-farm trials are recommended.

Keywords: Tsara; pigeon pea leaves; concentrate mixture; begait sheep; hay basal diet; economic advantage; Tigray Region, Ethiopia.

1. INTRODUCTION

Trees or bushes that animals graze on for food are referred to as browse species. In mixed crop and livestock production systems. These species have the ability to improve subpar diets, fix atmospheric nitrogen, offer fuel and shelter, and help conserve soil and water [1]. Tree fodders are crucial for giving grazing ruminants the nutrients they need in dry and semi-arid areas, where a lack of feed is a major barrier to livestock productivity. They participate in the intricate relationships that exist between crops, animals, and plants [2]; Tree fodders are important sources of nourishment for grazing ruminants and as supplements to improve the productivity of herbivores fed on low quality feeds [3].

Most browses plants have high crude protein content, ranging from 10 to more than 25% on dry matter basis; they may be considered as a more reliable feed resource of high quality to develop sustainable feeding systems and in increasing livestock productivity [4,5]. Thus, there is a pressing need to evaluate the potential and feed values of the indigenous browse plants, i.e., multi-purpose trees and shrubs so that they could be used in developing sustainable feeding standards.

Indigenous multipurpose browse species are well known to farmers and better adapted to the environments than exotic and are commonly used by farmers [6]. As a result, they are widely used throughout the nation, albeit without a scientific foundation. Although their potential as fodder has not received much attention, they represent significant feed resources in traditional animal agro-forestry systems found across the tropics [7]. In order to set feeding standards that are supported by science and to maximize the use of native browsing plants in the region's traditional animal agroforestry systems, such as Tsara and Pigeon Pea leaves, it is imperative that their potential and feed values be assessed [8].

In the North Western Zone of Tigray region in northern Ethiopia, the assessment of browse species as supplements for livestock, with a focus on Tsara (*Pterocarpus lucens*) and Pigeon Pea (*Cajanus cajan*) leaves, compared to concentrate mixtures, is significant. Begait sheep are fed hay along with this mixture as a basal diet. This evaluation is driven by the need to assess the economic advantages of utilizing browse species as an alternative to expensive concentrate feeds, which are often inaccessible to many farmers. By understanding the economic benefits of incorporating browse species as supplements, it becomes possible to provide insights into feeding standards and promote sustainable livestock production in the region.

1.1 Objectives

To determine the economic advantage of supplementing different levels of *Tsara* (*Pterocarpus lucens*) and pigeon pea (*Cajanus cajan*) leaves relative to concentrate mixture.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The study was conducted at Shire-Maitsebri Agricultural Research Center (SMARC), Tselemti District, North Western zone of Tigray Regional State, Ethiopia. Which is located 405 km far to the North West of Mekelle, the capital of the region, 85 km far to the South of Shire along the Gondar way and 1172 km far from Addis Ababa, capital of Ethiopia. Elevation ranges from 800 to 2870 meters above sea level (masl) and its coordinates are 38° 08' E longitude and 13° 05' N latitude. The region experiences 758 to 1100 mm of rainfall on average per year, with a monomodal pattern from June to September and the annual range of temperatures is 16 to 38°C.

2.2 Experimental Animals and their Management

The evaluation employed sheep of the Begait breed. We bought 25 yearling intact male sheep from the local market in Shiraro, weighing an average of 24.2±1.1 kg (mean±SD) when they were live. Dentition and inquiries to the owners provided information on the animals age. For 21 days, the sheep in the experimental region were kept under quarantine. They received deworming, anthrax and ovine pasteuruolosis vaccinations, as well as sprays against internal and external parasites, throughout this period of confinement.

2.3 Experimental Feed Preparation

In the Tselemti district, *Pterocarpus lucens* (Tsara) leaves were gathered from individual farmlands, communal grazing grounds, area fences, and water shadows. The leaves of a stand tree were gathered by handpicking the edible leaf sections and lopping off the plant's smaller branches. The Shire Maitsebri Agricultural Research Center experimental site and the nearby farmers' irrigated land were the sources of the pigeon pea leaf collection. The gathered leaves were subsequently carried in fresh batches and let to air dry in the shade for roughly five days, or until they could be easily crushed by twisting. Ultimately, the dried feeds were thoroughly combined, bundled into bags, and carefully kept in a dry concrete store with enough ventilation. The pigeon pea and *Pterocarpus lucens* leaves needed for the entire experiment were once harvested in the first three weeks of September when the plants were still in their pre-pod stage, or leafy stage. The concentrate feed was made up of three parts rice bran to one part sesame seed cake (75 RB: 25 SSC), with the rice bran coming from Medhanialem rice dehuling cooperatives and the sesame seed cake coming from nearby sesame oil extractors. Hay for the experiment, which served as the basal diet, was gathered from the Shire Maitsebri Agricultural Research Center, baled, and kept in a concrete floor that was well ventilated to prevent mold growth and spoiling. Table 1 shows the cost of the experimental feeds.

Pic. 1a. Begait Sheep used for the experiment

Pic. 1b. Housing of the experimental sheep

Table 1. Summary of feed costs

Feed Items	Cost in ETB
Hay	3.75ETB/Kg DM
Tsara leaf collection	15.00 ETB/Kg DM
Pigeon pea leaf collection	10.00 ETB/ kg DM
Concentrate mixture (75 kg RB + 25 kg SSC)	31.25 ETB/kg DM

ETB= Ethiopian Birr; kg= kilo gram; RB= rice bran; SSC= sesame seed cake


Pic. 2a. Tsara (*Pterocarpus lucens*) tree


Pic. 2b. Pigeon pea (*Cajanus cajan*) shrub

2.4 Experimental Design and Dietary Treatments

The study employed a Randomized Complete Block Design (RCBD) with five blocks and treatments (five sheep per treatment). Based on their starting body weight, the experimental sheep were divided into five blocks of five animals each, and each block was assigned to a separate corral. Randomly selected sheep within a block were given one of five dietary treatments: 400g DM Tsara leaves (T2), 320g DM pigeon pea leaves (T3), 360g DM mixtures of Tsara and pigeon pea leaves (T4), and 300g DM concentrate mixture (T5). Hay was given as the sole dietary treatment (T1).

2.5 Feeding Trial

The feeding trial lasted 90 days after a 15-day period of acclimatization or quarantine to the experimental meals and enclosures. Throughout the feeding trial, the experimental sheep were given the supplement meals in two equal parts at 08:00 and 16:00 hours every day. The basic meal was provided with a 20% adjustment for refusal. Each animal's feed refusals were weighed, noted, and the daily feed intake of each experimental sheep was computed from the difference between the daily offer and refusal. Following an overnight fast, the experimental sheep's initial and final body weights were measured twice in a row using a hung weighing balance with a 50 kg weighing capacity at the start and end of the experiment. Throughout the trial period, follow-up body weight measurements were taken at 10-day intervals to ascertain the weight change. The following formulas were used to determine feed conversion efficiency and average daily body weight gain:

$$\text{Average daily body weight gain} = \frac{\text{Final body weight} - \text{Intial body weight}}{\text{Number of feeding days}}$$

$$\text{Feed conversion efficiency} = \frac{\text{Average daily body weight gain in gram}}{\text{Daily dry matter intake in gram}}$$

2.6 Partial Budget Analysis

Using [9] Upton's methods, a partial budget analysis experiment were conducted to assess the economic profitability of supplementing regimens. An estimate of the study's total cost and profit analysis may not be provided by this kind of analysis. It does not take into account additional expenditures such as mineral licks, labor, housing, or veterinary services, which were common for all treatments; instead, it solely entails the computation of significant variable costs and benefit gains or losses from the sell price of sheep. Each experimental feed's purchase price was noted, the market value of sheep was evaluated in nearby animal markets, and knowledgeable sheep dealers made an educated guess as to how much each experimental sheep would cost.

Subtracting the buying price from the selling price of sheep in each treatment gave the total return (TR) for the analysis. The purchase price of each treatment feed and the actual feed intake for the entire feeding period were multiplied to determine the cost of feeds. The total cost incurred by each animal during the trial period in each treatment was then added, and the average was determined to be the total variable cost (TVC). Total variable costs (TVC) were deducted from total returns (TR) to determine net return (NR). The difference between the change in total return (ΔTR) and the change in total variable costs (ΔTVC) was used to compute the change in net return (ΔNR). The term "marginal rate of return" (MRR) refers to the percentage increase in net return (ΔNR) that is linked to every extra unit of expenditure (ΔTVC).

$$\text{MRR}\ (\%) = \frac{\Delta\text{NR}}{\Delta\text{TVC}} X100$$

2.7 Statistical Analysis

Analysis of variance (ANOVA) was performed on the study's data using SAS (11) version 9.2's General Linear Model (GLM) technique. The Tukeys studentized range (HSD) test was used to compare the differences in treatment means.

3. RESULTS AND DISCUSSION

3.1 Dry Matter Intake

Table 2 shows the Begait sheep's average daily dry matter intake (DMI) during the course of the feeding study. The supplemented groups (T2, T3, T4, and T5) had similar hay intakes, with the exception of T2, which had a higher intake than T4 ($P < 0.05$). The hay intake was highest for T1 ($P < 0.05$). The non-supplemented group (T1) may have consumed more hay because they were trying to meet their dietary needs. But prior research has indicated that supplementation can lead to an increase in hay consumption. [10] Observed that when Wogera sheep were fed grass hay as a basal diet and supplemented with 300 g/day brewery dried grain, cottonseed cake, and their mixture, the intake of the basal diet hay increased from 623.7 g/day in the control group to the range of 640.9 - 653.9 g/day in the supplemented group. The study's hay DMI result exceeded that of [11], who reported on yearling Tigray highland sheep rams supplemented with graded amounts of air dried *Acacia saligna* leaves (100 - 400 g/day) and 200 g/day wheat bran. The control group's DMI was 751.73 g/day, while the supplemented group's DMI was 695.28 - 724.35 g/day. For T2, T3, T4, and T5, the supplement feed consumption was 97.3, 85.84, 97.56, and 99.89%, respectively. The Begait sheep breed's comparatively higher body weight may be the primary cause of these disparities.

Begait sheep fed hay as a basal diet and supplemented with Tsara (*Pterocarpus lucens*) exhibited the highest total DMI over the feeding period, with T2 showing the highest DM intake, followed by T4, T5, and T3. T1, representing the non-supplemented group, had the lowest DM intake during the study period. All dietary treatments showed fluctuations in DMI, which could be impacted by meteorological factors as temperature and precipitation.

3.2 Body Weight Change

Table 3 shows the daily body weight increase (ADG) and body weight change of Begait sheep fed hay and supplemented with Tsara (*Pterocarpus lucens*), pigeon pea (*Cajanus cajan*), a mixture of Tsara and pigeon pea leaves, and concentrate mixture. The experimental sheep's starting body weights were comparable between treatments ($P>0.05$). However, the final body weight, body weight change, and ADG varied significantly among treatments ($P<0.001$). Because the initial body weight of the sheep in T1 was slightly greater, the ultimate body weights of T3 and T4 were comparable to the non-supplemented group (T1). But out of all the treatments, T1 had the least change in body weight and ADG. T5 had the greatest body weight change and ADG among the supplemented treatments, followed by T2, T3, and T4 ($P<0.001$). Expectations for a hay diet with crude protein (CP) below the maintenance threshold seem to be at odds with the ADG of 31 g/day for sheep fed exclusively on the basal diet (T1) [12]. This may be explained by the sheep in the control condition consuming a high amount of the basal food, which allowed them to get enough nutrients for a positive ADG. Sheep in T5, which were fed the concentrate mixture, had twice as much ADG as sheep in the diets containing pigeon peas. This implies that Tsara might be a more beneficial supplemental food than pigeon pea. It also emphasizes how crucial it is to take anti-nutritional factors and the nutrient content of forages into account when figuring out how much supplementation is necessary.

Furthermore, the body weight change increased throughout the experiment for all the supplemented treatments. T2 and T5 showed higher increases in body weight compared to other treatments.

In the non-supplemented sheep (T1), the animals exhibited positive weight gain throughout the experimental period. This indicates that the basal diet of hay alone was sufficient to support weight gain in the sheep, although supplementation with Tsara leaves, pigeon pea leaves, and the concentrate mixture further enhanced their growth [13]. In summary, the supplementation of Tsara, pigeon pea, and concentrate mixture led to significant improvements in body weight change and ADG compared to the non-supplemented group. Tsara and the Concentrate mixture (T5) appeared to be particularly effective in promoting higher body weight gains in Begait sheep.

3.3 Partial Budget Analysis

The partial budget analysis of the experiment is given in the Table 4. The partial budget analysis

result indicates that the total return obtained from the trial was 1324, 2374, 1724, 1924 and 3024 ETB/head of the sheep fed diets T1, T2, T3, T4 and T5, respectively. In addition, the net return from the experimental sheep fed on the diets T1, T2, T3, T4 and T5 was 991.5, 1541.50, 1183.60, 1232.95 and 1879.95 ETB, respectively.

Table 2. Daily dry matter intake of *Begait* sheep fed hay and supplemented with *Tsara* (*Pterocarpus lucens*), pigeon pea (*Cajanuus cajan*), mixture of *Tsara* and pigeon pea leaves, and concentrate mixture

Intake (g/day)	Treatment feeds						
	T_1	T_2	T_3	T_4	T_5	SEM	SL
Hay DM	985.19^{a}	910.18^{b}	868.68^{bc}	850.57^{c}	891.77^{bc}	11.77	***
Supplement DM	-	389.06^{a}	274.69^{c}	351.24^{b}	299.67^{c}	6.22	***
Total DM	985.19^{c}	1299.24^{a}	1143.37^{b}	1201.82^{b}	1191.44^{b}	14.02	***
DMI (% BW)	3.61^{b}	4.01^{a}	4.02^{a}	4.17^{a}	3.56^{b}	0.06	***

*$^{a-d}$mean values in a row having different superscripts differ significantly; ***P < 0.001; SL = significance level; SEM = standard error of the mean; DM = dry matter; BW = body weight; CM= concentrate mixture (75% wheat bran and 25% sesame seed cake); T_1 = Hay adlibitum ; T_2 = Hay ad libitum + 400 g DM/day Tsara; T_3 = Hay ad libitum + 320 g DM/day pigeon pea; T_4 = Hay ad libitum + 360 g DM/day Tsara + pigeon pea; T_5 = Hay ad libitum + 300 gDM/day Concentrate mixture*

Table 3. Body weight change and Average daily gain of Begait sheep fed hay and supplemented with Tsara (*Pterocarpus lucens*), pigeon pea (*Cajanus cajan*), mixture of Tsara and pigeon pea leaves, and concentrate mixture

Parameters	Treatment feeds					SEM	SL
	T_1	T_2	T_3	T_4	T_5		
Initial body weight (kg)	24.52	24.76	23.76	23.96	23.84	0.41	ns
Final body weight (kg)	27.28^{b}	32.44^{a}	28.4^{b}	28.8^{b}	33.44^{a}	0.38	***
Body weight change (kg)	2.76^{d}	7.68^{b}	4.64^{c}	4.84^{c}	9.60^{a}	0.17	***
ADG (g/day)	30.67^{d}	85.33^{b}	51.56^{c}	53.78^{c}	106.67^{a}	1.83	***

*$^{a,-d}$mean values in a row having different superscripts differ significantly; ns= not significant; *** P<0.001; SL= significance level; SEM = Standard error of the mean; ADG= average daily gain; TDMI= total dry matter intake; CM= concentrate mixture (75% wheat bran and 25% sesame seed cake); T_1 = Hay ad libitum ; T_2 = Hay ad libitum + 400 g DM/day Tsara; T_3 = Hay ad libitum + 320 g DM/day pigeon pea; T_4 = Hay adlibitum +360 g DM/day Tsara +pigeon pea; T_5=Hay adlibitum + 300gDM/day Concentrate mixture*

Table 4. Partial budget analysis of Begait sheep fed hay and supplemented with Tsara (*Pterocarpus lucens*), pigeon pea (*Cajanus cajan*) leaves and concentrate mixture

Parameter	Treatments				
	T_1	T_2	T_3	T_4	T_5
Number of animals	5	5	5	5	5
Purchase price of sheep (ETB/head)	3276	3276	3276	3276	3276
Total grass hay intake (kg/head)	443.35	409.60	390.90	382.75	401.30
Total supplement feed intake (kg/head)	0	175.10	123.60	158.05	134.85
Total cost of grass hay (ETB/ head)	332.50	307.20	293.20	287.05	301.25
Total cost of supplement feed (ETB/ head)	0	525.30	247.20	404.00	842.80
Total variable cost (ETB)	332.50	832.50	540.40	691.05	1144.05
Sale of sheep (ETB/ head)	4600	5650	5000	5200	6300
Total Return (ETB)	1324	2374	1724	1924	3024
Net return (ETB)	991.50	1541.50	1183.60	1232.95	1879.95
Change in net return (∆NR in ETB)	-	550	192.10	241.45	888.45
Change in total variable cost (∆TVC in ETB)	-	500	207.90	358.55	811.55
MRR% (∆NR/∆TVC)	-	1.10	0.92	0.67	1.09

ETB = Ethiopian Birr; MRR = marginal rate of return; CM= concentrate mixture (75% Rice bran and 25% sesame seed cake); T_1 = Hay ad libitum ; T_2 = Hay ad libitum + 400 g DM/day Tsara (Pterocarpus lucens) ; T_3 = Hay ad libitum + 320 g DM/day pigeon pea(Cajanus cajan); T_4 = Hay ad libitum +360 g DM/day Tsara (Pterocarpus lucens) + pigeon pea (Cajanus cajan); T_5=Hay ad libitum + 300g DM Concentrate mixture

Experimental sheep fed a concentrate mixture consisting of 75% rice bran and 25% sesame seed cake obtained higher net income (1879.95 ETB per head). This was followed by Tsara (*Pterocarpus lucens*) leaves, a mixture of pigeon pea (*Cajanus cajan*) leaves, and Hay, in that order. However, sheep supplemented experimental diet T1 (Hay *ad libitum*) earned a lowest net return (991.50 ETB per head) as compared to the other supplemented groups. The variations in the sheep's selling price as well as the variations in the sheep's intake and the expense of the supplemental feeds among the treatments are the primary causes of the variations in total return, net return, and marginal rate of return among the treatment feeds. The marginal rate of return (MRR%) which measures the increase in net return and the effects of the additional cost in a new technology on additional net return, in this feeding trial experiment was 110, 92.40, 67.34 and 109.48 for T2, T3, T4 and T5, respectively. This indicates each additional unit of one Ethiopian Birr per sheep to procure supplement feed results in a profit of 1.10, 0.92, and 0.67 and 1.09 Birr benefit for T2, T3, T4 and T5 respectively, as compared to the sheep in (T1).

The results indicated that the sheep fed the concentrate mixture (T5) had the highest net income, followed by those fed Tsara leaves (T2), a mixture of pigeon pea and Tsara leaves (T4), pigeon pea leaves (T3), and Hay alone (T1). The differences in total return, net return, and MRR among the treatments are mainly attributed to variations in selling prices of the sheep and differences in the intake and cost of the supplement feeds [14].

4. CONCLUSION AND RECOMMENDATIONS

In conclusion, the research findings indicate that supplementing Begait sheep with Tsara (*Pterocarpus lucens*) leaves, Pigeon pea (*Cajanus cajan*) leaves and concentrate mixture had positive effects on both body weight changes and economic returns. The treatments concentrate mixture (T5) and Tsara (*Pterocarpus lucens*) leaves (T2) resulted in higher total returns, net returns and body weight gains compared to the non-supplemented group (T1).

The results of the partial budget analysis revealed that the concentrate mixture returned the highest net income (1879.95 ETB), followed Tsara leaves (1541.50 ETB), Pigeon pea leaves (1183.60 ETB), mixtures of Tsara and Pigeon pea leave (1232.95 ETB) and hay (991.50 ETB), respectively. Accordingly, the marginal rate of return (MRR) was higher in T2 (110%) followed by T5 (109%), T3 (92%) and T4 (67%), respectively. Based on the partial budget analysis result, it was recommended that sheep producers could use Tsara (*Pterocarpus lucens*) leave, concentrate mixture (75% rice bran and 25% sesame seed cake), Pigeon pea (*Cajanus cajan*) and mixtures of Tsara (*Pterocarpus lucens*) and Pigeon pea (*Cajanus cajan*) leaves based on their order of importance. Therefore, from this study, supplementation of sheep with *Pterocarpus lucens* (T2) leaves and concentrate mixture (T5) was recommended economically feasible considering the net return and the marginal rate of return (MRR). However, pigeon pea (T3) and the mixture of *Tsara* and pigeon pea (T4) can be used as an alternative feed resource in areas where the availability of concentrate mixture is inadequate. Further research and on-farm trials are recommended to validate these findings and optimize the utilization of these feed resources in the local context.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The Author hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of the manuscripts.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://prh.globalpresshub.com/review-history/1679