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# EFFECT OF SUPPLEMENTATION OF LOCAL BREWERY BY-PRODUCTS ON FEED INTAKE, BODY WEIGHT CHANGE AND ECONOMIC EFFICIENCY OF WOYTO-GUJI GOATS FED HAY-BASED DIETS

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## ABSTRACT

**Local brewery byproducts such as atella and tata, resulting from several fermented beverages, are used as animal feed in Ethiopia. However, there is no sufficient information on the nutritional value of those feed resources for animals. The objective of this study was to evaluate the effects of supplementing local brewery by-products on feed intake, body weight change, and economic profitability of Woyto–Guji goats fed on hay. Twenty-four yearling intact Woyto-Guji male goats were used. The experiment was conducted using a completely randomized block design. The goats were blocked into six groups of four animals based on initial body weight and randomly assigned to four different dietary treatments: hay alone (T1); hay combined with atella (T2); hay combined with tata (T3); and hay combined with an atella-tata mixture (1:1) (T4). The crude protein content of hay, atella, tata, and the atella-tata mixture used in this study were 7.35, 18.47, 17.51 and 17.86%, respectively. Dry matter intakes of 564.56 (T1), 810.27 (T2), 850.37 (T3), and 945.85 (T4) g/day, and crude protein intakes of 45.27 (T1), 104.18 (T2), 103.79 (T3), and 112.96 (T4) g/day were recorded. Total body weight gains were 2.76, 8.03, 6.15 and 9.72 Kg for the same treatments, respectively. Atella and tata, either supplemented alone or combined, increased body weight. The highest body weight gain was recorded in goats fed atella-tata mixture. All treatments had a positive net return.**

**Keywords:** Tata, atella, intake, body weight.

## INTRODUCTION

Small ruminants are an integral part of livestock production in Sub-Saharan Africa. Sheep and goats are mainly kept for immediate cash sources, milk, meat, wool, manure, and saving or risk distribution. According to the Central Statistics Agency (CSA, 2021) of Ethiopia, the total goat population in the country was estimated to be about 52.5 million, corresponding to 69.55% females and 30.45 % males, respectively. Feed is the most important input in livestock production and its adequate supply (quality & quantity) throughout the year is an essential prerequisite for livestock production. Similarly, availability and cost of conventional feed resources are critical problems at the country level. Hence, there is a search for alternative feed sources that can help to reduce feed costs.

Fermented local and industrial by-products of brewing have been used as non-conventional feedstuffs, mainly as protein and energy supplements. Breweries across the country produce several types of by-products, while

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domestic brewing and distillation are also common practices. Domestic and modern breweries produce a total of 635,343 ton of by-products in Ethiopia (FAO, 2019). The efficient use of by-products will help to decrease feeding costs, which generally constitute about 70 percent of the total animal production costs. Brewery atella is a wet residue by-product resulting from the short fermentation (less than a week) of mixtures of different grains, while liquor atella is a grain by-product remaining after alcoholic distillation (Mekasha et al., 2003). A total volume of 69,300 liters per week of local beer (tella) is produced and sold in different cities of the country; particularly in the Addis Ababa area, Tigray and Amhara (Alemayehu et al., 2016; Ayenew et al., 2009), leading to the production of approximately 19,611 liters of atella (Yohannes et al., 2013). Only a small proportion of atella is used as feed, and large quantities accumulate at production sites, thus causing disposal and public health problems (Solomon, 2007). In fact, it is a typical urban by-product used in more than 80% of intra-urban dairy farms of Ethiopia, being more available in the central than in the eastern zone of Ethiopia (Yayneshet et al., 2016).

Another byproduct used for feed is tata, which results from the traditional home-brewed local beer (Chaka). It a typical rural by-product that is produced year-round in large quantities in the study area and surroundings. Short-term feeding of by-products is a matter of farmers' interest because of its low cost and its presumed nutritional value. However, the real nutritional value of local brewery byproducts remains unknown in the study area. Similarly, there is a lack of information on whether atella alone or mixed with tata improves animal performance. Therefore, the objective of this research was to evaluate the effects of the supplementation of local brewery by-products (atella and tata) on feed intake, body weight change, and economic efficiency of Woyto-Guji goats fed hay-based diets.

## MATERIALS AND METHODS

### Description of the study area

The experiment was conducted in Konso Zone Agricultural Department, Karat (capital city of Konso), Konso Zone, South Ethiopia. It is one of the zones located in the Great Rift Valley, about 595 km south of Addis Ababa ($5^0$10′0′′ to $5^0$40′0′′N latitude and $37^0$0′0′′ to $37^0$45′0′′ E longitude), at an altitude of 501- 2,000 meters above sea level. The main agro-ecological divisions correspond to 70% lowlands (Kola) and 30% tropical midlands (Weinadega) (KDAO, 2012). Total population reaches 338,729 inhabitants (male = 171,646 and female = 167,083), with an urban population of 53,125 (male = 26,347 and female= 26,778). The livestock and poultry population of the zone is as follows: cattle = 558,800; sheep = 353,134; goats = 621,429; chickens = 1,363,594; and donkey = 12,908 (CSA and RBFED, 2020).

The area has unreliable rainfalls not exceeding 800 mm (601-1200 mm) per year, with high rainfall concentrated in July and August. Temperature ranges from 15 °C at night to 32 °C during the day (mostly between 18 and 28 ºC). Konso Zone is bordered in the south by the Oromia Region, in the west by the Debub Omo Zone, in the north by the Dirashe Special Woreda, in the northeast by Amaro Special Woreda, and in the east by Burji Special Woreda (KDAO, 2012).

### Experimental animals and management

Twenty-four yearling intact Woyto-Guji male goats with 17.7 ± 1.44 kg (mean ± SD) initial body weight (BW) were purchased from local market (kolme and masale) for the experiment. Age was determined by dentition and information obtained from the owners. The animals were quarantined for two weeks for adaptation to the environment and health status evaluation; vaccinated against the common diseases of the area; dewormed against internal parasites and sprayed against external parasites. Each goat was identified with a collar around the neck and kept in individual feeding pens for two weeks for adaptation to the experimental diets (prior to data recording) and throughout the experimental period. A goat shed of 13 x 4 (52 square meter) with 1.5 square meter (1.5 m x 1 m) per animal was built, with a chute system of 14.5 m in length leading to each pen for management. The shed had a concrete apron floor; wooden wall, with its circumference partially covered with plastic. The goats were fed separately, monitored daily for signs of discomfort, and daily feed offers and refusals were recorded. The supplements and water were offered in plastic buckets purchased from the market. Supplementary feeds were offered daily in two equal portions at 8:00 a.m. and 4:00 p.m., while mineral salt and water was offered *ad libitum*.

### Feed preparation

Natural pasture hay was purchased from private grazing lands. To make hay, pasture was cut, dried to prevent shed from moisture, chopped manually approximately into about 3- to 5-cm lengths and mixed thoroughly. Subsequently, hay was stored in a dry and well-ventilated barn to maintain its quality and used as a basal diet throughout the experiment. Atella

and tata (made from the fermentation of maize, sorghum or barely) were purchased from local Chaka and Arekie producers. The collected atella and tata were dried by spreading on a plastic sheet under shade to reduce moisture content at the required level of 12-14% and stored in sacks in a well-ventilated room to avoid mold growth and spoilage during the experimental period.

**Experimental design and treatment**

The experiment was carried out using a randomized complete block design with four treatments and six blocks for 90 days. The experimental goats were blocked into six blocks based on their initial BW and placed randomly in individual pen. Initial BW was determined as a mean of two consecutive weight measurements that were taken after withholding feed and water overnight. Goats within a block were randomly assigned to one of the four dietary treatments. The treatments were *ad libitum* feed of hay alone (T1); *ad libitum* feed of hay + 2% of BW atella (T2); *ad libitum* feed of hay + 2% of BW tata (T3); *ad libitum* feed of hay + 2% of BW of atella and tata mixed (1:1 ratio).

**Feeding trial**

At the end of the quarantine and adaptation periods to the experimental pens and diets, the feeding trial was started and conducted for 90 days.

The amounts of supplements for individual goats per feeding were 2% of BW and adjusted according to BW at the beginning and every two weeks until the end of the feeding period. Supplements were offered twice on a daily basis in separate feeding troughs at 02:00 a.m. and 08:00 p.m. (local time). Natural pasture hay (the basal diet) was provided to goats for ad libitum intake to permit at least 20% refusals. Each goat had free access to clean water and common salt throughout the entire experiment.

Daily feed offered and the corresponding refusals of grass hay were recorded every morning to determine daily and total feed intakes. Both the basal and supplemental feed intake was determined. Daily hay refusals were pooled per treatments every week. Feed intake was calculated by subtracting feed refusal from feed offered on dry matter (DM) bases. Samples were taken from batches of feed offer, thoroughly mixed and sub-sampled for chemical analysis. Feed refusal samples were taken per animal pooled on treatment basis. To determine weight change, subsequent BW measurements were taken. Initial BW was determined by taking the mean of two consecutive weight measurements after overnight fasting and subsequent BW measurements made at intervals of two weeks throughout the experimental period after overnight fasting and before offering daily rations. BW measurements were made by using a suspended spring balance capable of reading up to 50 kg. Weight gain was calculated as the difference between final and initial BW. Average daily BW gain was calculated as the difference between final and initial BW divided by the number of feeding days. The total BW changes was obtained by subtracting initial BW from final BW. Feed conversion efficiency (FCE) was estimated as a ratio of average daily gain (ADG) and daily dry matter intake (DMI).

$$BWC = BWF - BWI;$$

Where: BWC is body weight change; BWF is final body weight; and BWI is initial body weight.

$$ADG = \frac{BWF\ (g) - BWI\ (g)}{No.\ of\ feeding\ days}$$

$$FCE = \frac{ADG\ (g)/}{DMI\ (g)}$$

**Chemical analysis**

The chemical compositions of feed samples and residues were analyzed at Arba Minch University, Abaya Campus Chemistry Laboratory. The samples were ground to pass a 1-mm sieve and used for laboratory analysis. The samples were analyzed on % DM basis for crude protein (CP), DM, while ash determination was performed according to the AOAC method (2005). The acid detergent fiber (ADF) and acid detergent lignin (ADL) components of each ingredient and feces were determined according to the procedures of Van Soest and Robertson (1985), while the nutrient detergent fiber (NDF) content was analyzed following the procedures of Van Soest et al. (1991). Ash content was determined by heating samples in a furnace at 550 °C for 4 hours and organic matter (OM) content calculated as DM minus ash. Nitrogen (N) content was determined following the micro-Kjeldahl digestion, distillation, and titration procedures (AOAC, 2005) and the CP content was estimated by multiplying the N content by 6.25 factors.

**Partial budget analysis**

Partial budget analysis was used to determine the profitability of the feeding regime by the method of Upton (1979). Only the major costs, the purchasing cost of goats and feed and benefit gained from selling price of goats, were involved in the calculation; costs like labor, housing, and veterinary service, which would be common for all treatments, were not considered. The data

were recorded, and market price of goats was assessed in the local animal market; the price of the experimental goats was estimated by experienced goat dealers and sold accordingly. The cost of hay and local byproducts was considered as total variable cost (TVC). The difference between purchase and selling prices of goats in each treatment was considered as total return (TR). Net income (NI) was calculated by subtracting TVC from TR:

$$NI = TR - TVC$$

The change in net income (ΔNI) was calculated by the difference between the change in total return (ΔTR) and the change in total variable costs (ΔTVC):

$$\Delta NI = \Delta TR - \Delta TVC$$

The marginal rate of return (MRR) measures net income (ΔNI) increases associated with each additional unit of expenditure (ΔTVC) and normally expressed as percentage:

$$MRR = \frac{\Delta NI}{\Delta TVC} \times 100$$

**Statistical analysis**

Data collected on intake and BW change parameters were analyzed using the general linear model (GLM) procedure of the Statistical Analysis system (SAS) version 9.1.3 (SAS, 2008). Mean differences from intake and BW change traits were compared using Turkey's Test (HSD). Probability values less than 0.05 were considered among means where the overall F test was significant ($P < 0.05$). The model used for data analysis was as follows:

$$Y_{ij} = \mu + T_i + B_j + E_{ij}$$

Where:
$Y_{ij}$ = response variable taken under treatment i;
$\mu$ = overall mean;
$T_{i=}$ i $^{th}$ treatment effect (feeds);
$B_{j=}$ j$^{th}$ block effect and
Eij = random error of i$^{th}$ treatment in the j$^{th}$ block.

## RESULTS AND DISCUSSIONS

**Chemical composition of the experimental feeds**

Table 1 shows the chemical composition of the experimental feeds used in this study. The CP content of the hay (7.35%) was low but adequate to meet the minimum CP level to allow for optimum microbial activity in the rumen, feed intake and BW change of the goats. This indicates that the hay used, even though it is of low quality, meets the minimum requirements for maintenance in terms of intake and digestibility of goats, which agrees with the 7-8% CP content reported in previous studies (Van Soest, 1991; Minson, 1990).

Simret (2005) reported a CP content of hay

**Table 1. Chemical composition of the supplemental feeds and hay refusals.**

| | Chemical Composition (g/kg) | | | | | |
|---|---|---|---|---|---|---|
| **Treatment feed** | **DM** | **Ash** | **CP** | **NDF** | **ADF** | **ADL** |
| Hay | 883.5 | 137.9 | 73.5 | 693.5 | 450.3 | 21.2 |
| Atella | 910.2 | 64.5 | 184.7 | 140 | 33.9 | 13 |
| Tata | 906.8 | 71.5 | 175.1 | 75.5 | 41.1 | 15.3 |
| Atella-tata mixture | 912.9 | 71.2 | 178.6 | 118.3 | 32.7 | 24.7 |
| Mean | 903.35 | 86.275 | 152.975 | 256.825 | 139.5 | 16.5 |
| SEM | 6.73 | 17.28 | 26.56 | 146.17 | 103.61 | 2.44 |
| **Hay refusals** | | | | | | |
| T1 | 916 | 119.6 | 42.9 | 726.4 | 581.1 | 53.3 |
| T2 | 844.5 | 117.4 | 48.1 | 763 | 459 | 37.6 |
| T3 | 866 | 114 | 40.3 | 705.9 | 477 | 40.6 |
| T4 | 905.5 | 125.3 | 50 | 743.9 | 522.8 | 35.9 |
| Mean | 883 | 119.07 | 45.32 | 734.8 | 509.98 | 41.85 |
| SEM | 16.75 | 2.37 | 2.25 | 12.2 | 27.25 | 3.94 |

DM= dry matter; ADF= acid detergent fiber; CP= crude protein; NDF= neutral detergent fiber; ADL=acid detergent lignin; T1= ad libitum feed of hay alone; T2= ad libitum feed of hay + 2% of body weight atella; T3= ad libitum feed of hay + 2% of body weight tata; T4= ad libitum feed of hay + 2% of body weight atella- tata mixture 1:1 ratio; SEM= standard error of the mean.

ranging between 7 and 9%, which is in agreement with the value obtained in the present study. The nutrient content variation of hay depends on species composition, stage of maturity at harvest, and the growing environment (Alemayehu, 2002; Adane, 2003). Kebede et al. (2017) reported values of 943, 39.7, 205, 301, 186 and 36.7 g/kg for DM, ash, CP, NDF, ADF and ADL for tata, respectively.

The NDF and ADF contents of the hay used in this study were comparable to the values of 67.2% and 46.4% reported by Simachew (2009) for hay, but slightly higher than the values of 62.1% and 43.6% reported by Bruk (2008) for NDF and ADF, respectively. The NDF content of tata was lower than that of atella and atella-tata mixture. The CP, NDF and ADF in the supplemented diets indicate that they can help to increase feed intake and BW gain of the goats. However, the ADL content was low in all dietary treatment, indicating that the nutrients are easily available to perform important body functions for goats. Shashie and Ayalew (2023) reported values of 222, 344, 267 and 89 for CP, NDF, ADF and ADL contents (g/kg) for atella, respectively. Tegene (2009) also found 187 g/kg CP, 535 g/kg NDF, 336 g/kg ADF and 214 g/kg lignin for atella. Similarly, a study conducted by Almaz et al. (2012) reported values of 938, 212, 347 and 214 g/kg of DM, CP, NDF and ADF for tella atella, respectively.

**Dry matter and nutrient intake**

Daily DM, OM, CP, NDF and ADF intakes of Woyto-Guji goat fed hay supplemented with local brewery by-products (atella, tata, and atella-tata mixture 1:1 ratio) are presented in Table 2.

The daily hay, supplement and total DM intake was significantly different (P<0.001) among all treatments. The supplemental feeds were consumed with no refusal by all goat groups. The daily hay DM intake was affected and showed significant difference (P<0.001) by supplementation.

In the present study, CP intake was lower for T1 compared to the rest of the treatments. The atella- tata mixture resulted in a more marked effect. This agrees with the results of Ajebu et al. (2014), who found that, compared to the supplementation of atella alone, a 50:50 mixture of katikala-atella optimized intake, BW change performance and feed conversion efficiency.

**Body weight change and feed conversion efficiency**

BW parameters and feed conversion efficiency are shown in Table 3. The supplemented goats achieved higher final BW than goats in the controlled treatment, whereas the supplemented treatments differ (P<0.001) from each other. BW gain, average daily weight gain and feed conversion efficiency follow a similar trend in the order of T4>T2>T3>T1 (P<0.001). This indicates that atella and tata can be used as a potential sources of feed livestock production.

The BW gain observed in the present study was greater than the range of 36.29-44.72 g/d observed in Somali goats supplemented with

**Table 2. Daily dry matter and nutrient intake of Woyto-Guji goat fed hay-based diets supplemented with local brewery by- products.**

| DM and nutrient Intake (g/d) | Treatments | | | | SEM | *P-value* |
|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | | |
| Hay DM | 564.56a | 434.41c | 485.14b | 564.7a | 13.059 | 0.001 |
| Supplement DM | ------- | 375.86a | 365.225a | 381.15a | 34.265 | 0.001 |
| Total DM | 564.56c | 810.27b | 850.365b | 945.85a | 31.348 | 0.001 |
| OM | 484.45c | 723.84b | 756.48b | 839.04a | 29.23 | 0.001 |
| CP | 45.267c | 104.18b | 103.785b | 112.955a | 5.8 | 0.001 |
| NDF | 387.465b | 346.142c | 362.455c | 429.478a | 8.05 | 0.001 |
| ADF | 238.092b | 207.388c | 230.108b | 256.35a | 6.43 | 0.001 |
| ADL | 30.117a | 21.22c | 26.647b | 30.208a | 0.85 | 0.001 |
| ASH | 80.107d | 86.43c | 96.012b | 106.81a | 2.42 | 0.001 |
| TDM (g/kg $W^{0.75}$) | 60.497d | 80.773c | 86.677b | 92.412a | 2.54 | 0.001 |

Different letters in the same row indicate significant differences between treatments at p<0.01; DM= dry matter; ADF= acid detergent fiber; CP= crude protein; NDF= neutral detergent fiber; OM= organic matter; SEM=standard error of the mean; Pr = probability; T1= ad libitum feed of hay alone; T2= ad libitum feed of hay + 2% of body weight atella; T3= ad libitum feed of hay + 2% of body weight tata; T4= ad libitum feed of hay + 2% of body weight atella- tata mixture at 1:1 ratio.

**Table 3. Body weight parameters and feed conversion efficiency of Woyto-Guji goats fed hay- based diets supplemented with local brewery by- products.**

| Parameters | Treatments | | | | SEM | *P-value* |
|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | | |
| Initial body weight (kg) | 17.85 | 17.65 | 17.7 | 17.6 | 0.29 | 0.6925 |
| Final body weight (kg) | 20.61c | 25.683ab | 23.85b | 27.317a | 0.65 | 0.001 |
| Body weight gain (kg) | 2.76d | 8.033b | 6.15c | 9.72a | 0.57 | 0.001 |
| Average daily gain (g/day) | 30.69d | 89.26b | 68.33c | 108a | 6.33 | 0.001 |
| FCE (g ADG/g TDMI) | 0.054c | 0.11a | 0.081b | 0.114 a | 0.0054 | 0.001 |

Different letters in the same row indicate significant differences between treatments at P <0.001; SEM=standard error of the mean; Pr = probability; g= gram; kg= kilogram; FCE= feed conversation efficiency; ADG= average daily gain; TDMI= total dry matter intake; T1= *ad libitum* feed of hay alone; T2= *ad libitum* feed of hay + 2% of body weight Atella; T3= *ad libitum* feed of hay + 2% of body weight Tata; T4= *ad libitum* feed of hay + 2% of body weight atella- tata mixture 1:1 ratio.

graded levels of peanut cake and wheat bran mixture in a study conducted by Simret (2005). The feed conversion ratio was comparable to values in the range of -0.006 to 0.13 reported by Mulu (2005). In addition, a study of Kebede et al. (2017) reported 77.4 g/day BW gain for goats supplemented with tata.

The increased live weight gain and average daily gain in supplemented animals compared to the control group might be explained by the higher total DM and CP intake and better digestibility of the dietary treatments. This suggests that the mixed supplements (tata and atella) result in better performance of goats than atella or tata supplemented alone. Diets that promote a higher gain rate would result in a greater efficiency than diets that do not allow rapid gain. This occurs because goats that rapidly gain weight utilize less of the total feed consumption for maintenance, and more would be available for gain. Sisay et al. (2019) reported average daily BW gains of 62-76 g/day for goats supplemented with different browse species and wheat bran mixtures. On the other hand, higher BW gains (75-133 g/day) were reported in Arsi-Bale goats fed with graded levels of pigeon pea foliage (Eleni et al., 2021). Feeding concentrate mixtures of wheat bran and noug (Guizotia Abyssinica) seed cake resulted in daily BW gains of 108.8 g in Afar goats under semi-intensive production systems (Anuar et al., 2020).

**Body weight (BW)**

BW was regressed on experimental days (weeks) (Fig. 1). The regression was significant ($R^2$=.760; P<0.001). The regression indicates the importance of using local brewery by-products as the determinant of the growth of goats fed natural pasture hay-based diets.

**Partial budget aalysis**

Partial budget analysis was conducted to assess the economic benefit of supplementation with atella, tata, and their mixture for Konso/ Woyto-Guji goats fed a basal diet of natural grass hay (Table 4). The partial budget analysis considered major costs and return per head of the experimental goats. There was a low total return and net return of 425 and 74.64 ETB per animal for the control treatment, respectively. The minimum net return might be explained by a lower BW gain and poor body condition, thus resulting in lower nutrient intake compared to that of the supplemented groups. T2 and T4 had higher net return as compared to T3. The difference in the net return among the supplemented treatments was mainly due to the difference in feed costs of the supplements and selling price of the goats in each treatment.

The higher profit obtained in T4 is due to the higher weight gain and better FCE and ADG values, which resulted in higher selling prices of the goats. The values of MRR in the present study are positive for supplemented groups, indicating that the by-products are economically viable; the higher the positive MRR, the more economically attractive the feed. The MRR showed that each additional unit of 100 ETB per goat cost increment resulted in 100 ETB and additional 151, 110 and 223 ETB benefit for T2, T3 and T4, respectively. Thus, local brewery by-products, particularly atella-tata mixture, can be used as a supplement to goats and obtain better economic returns.

## CONCLUSION

The results of this study indicate that supplementation of local brewery by-products (atella and tata) improved feed intake and body weight gain of Woyto-Guji goats fed hay-based

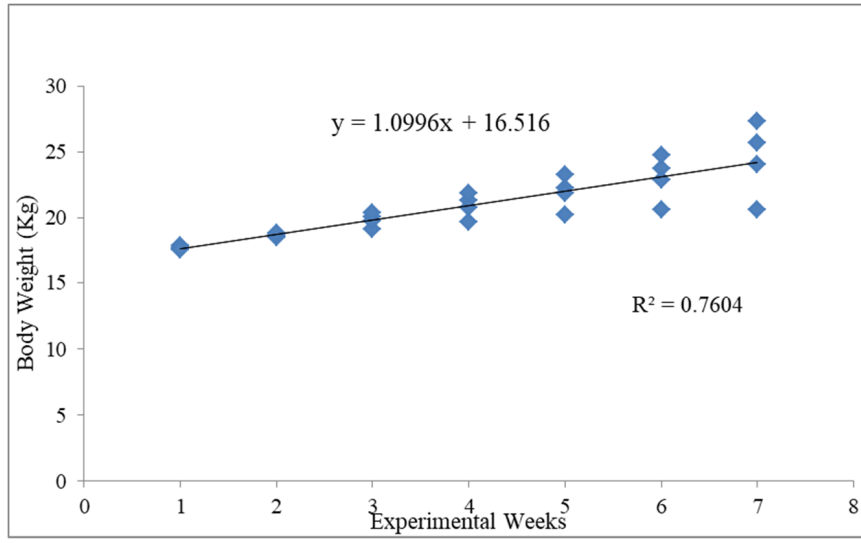


**Fig. 1. Regression of Live weight over experimental Weeks**

**Table 4. Partial budget analysis of Woyto-Guji goats fed hay-based diets supplemented with local brewery byproducts.**

| | Treatments | | | |
|---|---|---|---|---|
| **Parameters** | **T1** | **T2** | **T3** | **T4** |
| Purchase price per goats (ETB) | 1,375 | 1,375 | 1,375 | 1,350 |
| Hay consumed (kg/goat) | 70.073 | 55.594 | 62.245 | 72.141 |
| Atella consumed (kg/ goat) | - | 37.164 | - | - |
| Tata consumed (kg/ goat) | - | - | 36.248 | - |
| AT consumed (kg/ goat) | - | - | - | 37.576 |
| **Feed costs** | | | | |
| Cost of hay (ETB/ goat) | 350.365 | 277.97 | 311.225 | 360.705 |
| Cost of atella (ETB/ goat) | - | 371.64 | - | - |
| Cost of tata (ETB/ goat) | - | - | 289.984 | - |
| Cost of AT (ETB/ goat) | - | - | - | 338.184 |
| TVC (ETB/ goat) | 350.365 | 649.61 | 601.209 | 698.889 |
| Gross return/selling price (ETB/ goat) | 1,800 | 2,550 | 2,325 | 2,900 |
| Total return (TR) (ETB/ goat) | 425 | 1175 | 950 | 1550 |
| Net return (ETB/ goat) | 74.635 | 525.39 | 348.791 | 851.111 |
| Change in total return (ETB/ goat) | - | 750 | 525 | 1125 |
| Change in net income (ΔNI) (ETB/ goat) | - | 450.755 | 274.156 | 776.476 |
| Change of total variable cost (ΔTVC) | - | 299.245 | 250.844 | 348.524 |
| MRR (ΔNI/ΔTVC) | - | 150.63 | 109.3 | 222.8 |

ETB= Ethiopian birr; ΔNI= change in net income; ΔTVC= change of total variable cost; MRR= marginal rate of return; NR= net return; TR= total return; T1= ad libitum feed of hay alone; T2= ad libitum feed of hay + 2% of body weight atella; T3= ad libitum feed of hay + 2% of body weight Tata; T4= ad libitum feed of hay + 2% of body weight atella- tata mixture 1:1 ratio.

diets. The combined use of atella and tata at 1:1 ratio (T4) resulted in the highest average daily gain of goats compared with separate supplementations. Supplementation of atella, tata or their mixtures also improves economic returns from goats.

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