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DETERMINATION OF BREWERY YEAST-TREATED CROP RESIDUES AS ANIMAL FEED RESOURCE

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ABSTRACT: The study evaluates the effects of brewery yeast to improve the nutritional value and in vitro digestibility of selected crop residues in Dessie Town, Amhara region, Ethiopia. The experiment was laid out in a completely randomised design (CRD) with a 3×5 factorial arrangement, i.e., three-selected crop residues (Teff straw, maize, and sorghum stover) with five levels of fermentation periods (0, 3, 6, 9, and 12 days). The mean crude protein (CP) values of brewery-spent yeast (BSY) treated Teff straw, maize stover, and sorghum stover treated crop residues were 7.85%, 14.3%, and 14.78%, respectively. Among proximate and detergent values of the interaction effect of fermentation period and crop residue type, dry matter (DM), crude protein (CP), estimated metabolizable energy (EME), acid detergent lignin (ADL), and neutral detergent fiber (NDF) content were significantly ($p < 0.01$) varied at different fermentation periods. While ash, organic matter (OM), and acid detergent fiber (ADF) content were highly significant ($p < 0.001$) variations between the interaction of crop residues and the fermentation period. The value of in vitro dry matter digestibility (IVDMD) and in vitro organic matter digestibility (IVOMD) of BSY treated crop residue was significantly ($p < 0.001$) varied for the interaction of crop residue type and fermentation period. The EME, IVDMD, and IVOMD of BSY treated crop residues were observed in the range of 7.54-10.64 MJ/kg, 54.44%-61.46%, and 47.14%-66.48%, respectively. Therefore, the study investigates how brewery yeast can enhance the nutritional quality and in vitro digestibility of certain crop residues in Dessie Town, Ethiopia. It followed a random design with three crop residues (Teff straw, maize stover, and sorghum stover) and six fermentation periods. Treated residues showed varying crude protein values and significant differences in in vitro digestibility and energy content. Therefore, utilizing brewery-spent yeast (BSY) presents a cost-effective and sustainable approach to enhancing the nutritional value and in vitro digestibility of crop residues. Further studies may explore the scalability of BSY treatments and their effects on livestock performance.

Keywords: Brewery spent yeast, Crop residue, In vitro digestibility, Nutritional value.

INTRODUCTION

Ethiopia is home to a huge number of livestock due to its vast and diverse agro-ecological zones and the significance of livestock in subsistence strategies. Indeed, Ethiopia has the largest livestock population in Africa, with 70 million cattle, 42 million sheep, 52 million goats, 8 million camels, and 56 million chickens (CSA, 2022). Despite the huge numbers and multiple roles of livestock, productivity remained very low in Ethiopia and unable to meet the demands of the rapidly growing population (Yigezu Wendimu, 2021). Numerous constraints are often associated with this, such as scarcity of feed, high incidence of diseases and parasites, limited genetic potential of local breeds, poor veterinary care, restricted credit availability, scarcity of land, and poor management techniques in all livestock production systems (Welay et al., 2018). Among these limits include low quality and insufficient amount of feed availability, particularly during the dry season, were identified as the major causes of low livestock productivity and it accounts about 80% of the overall production cost (Duguma and Janssens, 2021).

Ruminant diets in Ethiopia are generally based on roughage feeds especially crop residues like Teff straw, maize and sorghum stover. The intake, in vitro digestibility and nutrient absorption of the crop residues are very poor because of high cell wall content and low essential nutrients. The nutrient content of crop residue cannot even support the maintenance requirements of the animals and consequently, the performance of an animal feeding crop residue is very low. Improving the nutritive value of the poor-quality feed resources is one option for proper utilization. Intake and utilization of low-quality roughage can be improved by different methods of treatments technologies (Duguma and Janssens, 2021).

Brewer's spent yeast (also known as residual yeast or excess yeast) is a common by-product of the brewing industry that is produced when the yeast used in fermentations is no longer usable and must be discarded (Jaeger et al., 2020). In recent years, there has been growing awareness in Ethiopia regarding the importance of improving the utilization of crop residues to address feed shortages and enhance livestock productivity (Duguma and Janssens, 2021). The nutritional value and in vitro rumen fermentation features of a study conducted on yeast-fermented maize dust and cassava pulp at several ratios (40:60, 20:80, and 0:100%) and ensiled for 15 days are improved (Ratchataporn et al., 2022). In accordance with Kim et al. (2015), the liquid brewery spent yeast mixed with cassava pulp at a ratio of 30%:0% increases

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the chemical composition and reduces *in vitro* gas production. Similarly, the use of brewery-spent grain (20%) into corn treated crop residue and total mixed ration boost in vitro digestibility and fermentation characteristics.

Treating crop residues through fermentation with brewery-spent yeast (BSY), can enhance their nutritional value, increase in vitro digestibility, and improve their suitability as animal feed (Terefe 2022, and 2023). This approach contributes to addressing feed shortages, particularly during the dry season, while also promoting the sustainable use of agricultural by-products. Teff straw, maize stover, and sorghum stover was likely based on their widespread availability in the study area (Dessie Town) and their significance as staple crop residues in Ethiopian livestock systems. The fermentation periods were systematically assessed; fermentation duration influences the nutritional improvement of the residues. These intervals provide insights into the dynamic changes in crude protein, in vitro digestibility, and energy content over time, helping to identify the optimal fermentation period for practical application (Terefe et al., 2022).

In Kombolcha Brewery industry, there is a huge amount of brewery-spent yeast dumping daily in the local environment. This may contaminate the local environment and cause public health hazard. However, this resource has an alternative advantage in enhancing the nutritionally poor contents of the roughage feed sources as the result of additive effect of the different inclusion rate. It is essential to create suitable methods of utilizing BSY as animal feed due to its affordability, high nutrient concentration (Jaeger et al., 2020). Hence, mixture of brewery yeast cell on poor quality forage and high grain diets can increase the nutritional value of the ration (Aubrey, 2017; Yadessa et al., 2023). Therefore, the main aim of this study was to investigate the effects of brewery yeast on the chemical composition and in vitro digestibility of selected crop residues fermented at different time.

MATERIALS AND METHODS

Description of the study area

The selected crop residue type (Teff straw, maize and sorghum stover) was collected from Dessie town, South Wollo Zone of Amhara Region. It is found in the north-central part of Ethiopia at a distance of 401km from Addis Ababa, which is the capital city of the country (Figure 1). Its topography varies from 2400-3000 meters above sea level. Geographically it lies on the intersection of 11°8′N and 39°38′E. Dessie town is subdivided into 5 sub-cities, 18 urban kebeles and 8 rural kebeles. It is located within the highland (Dega) agro-climatic zone and it has a bimodal rainfall distribution where the major annual rain fall season occurs in winter (Meher) (May to end of September) and short rainy season occur in autumn and spring (Belg) (beginning January to April). Dessie typically has mean annual rainfall is 1120 mm and mean annually temperature ranges from 15.0°C (59.0°F) to 26.78°C (80.2°F).

Dessie town is located within Dessie Zuria District and suitable for the production of different livestock and crop production. Small-scale farming is considered the most prevalent method for maintaining a subsistence economy at the household level. Farmers usually own draught animals. The crops are produced during two cropping seasons, *Meher* and *Belg*. During *Belg* season, the most important crops are barley, pea, whereas, wheat, maize, bean, and Teff are the most important one in *Meher* season. Based on the district agriculture office, the livestock population of the Dessie Zuria District has 22,831 cattle, 3,179 goats, 25,875 sheep, 1,259 horses, 578 mules, 5,656 donkeys, 1,155,661 hens and 619 bee colonies are found as documented.

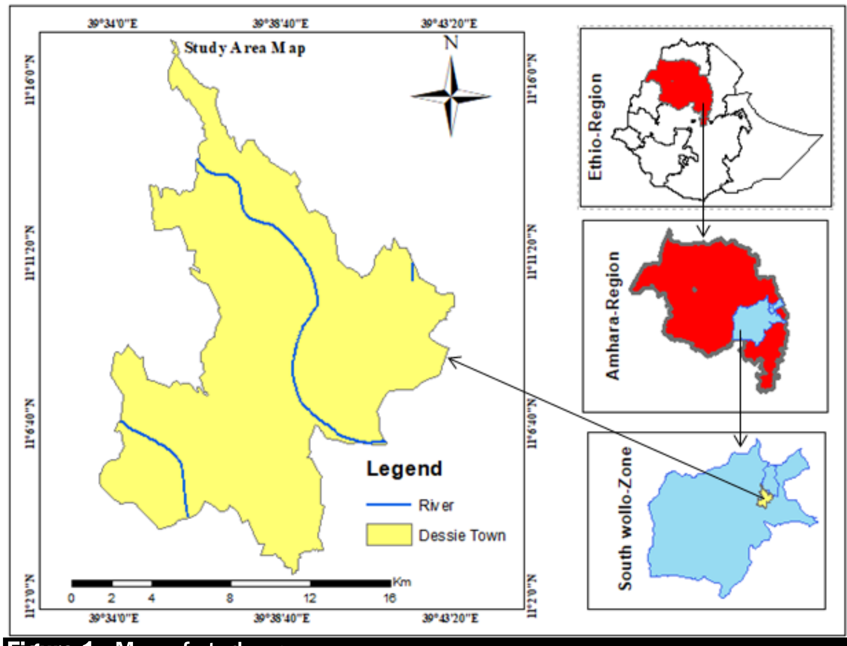

Figure 1 - Map of study area.

Experimental materials and sample preparation

Liquid brewer spent yeast (LBSY) was obtained from BGI Kombolcha Brewery Industry, Ethiopia. This material was collected with plastic buckets (20 litters), transported in airtight Jerica, and packed until utilized via proper experimental procedure. Liquid brewery spent yeast (LBSY) was stored for approximately 12 hours and allowed to cool before diluted with water in a 1:5 ratios, respectively (Terefe et al., 2022). The crop residues such as Teff straw, maize and sorghum stover was obtained from Dessie town. Liquid brewery spent yeast (LBSY), distilled water (DW), polyethylene plastic bag (PPB) is used to ensiling the materials, electrical chopper machine (ECM) was used for cutting/chopping the crop residue at recommended sieve size. Homogenizer is used to mixed crop residues with brewery by-products; sensitive balance is used to measuring the exact amount of crop residue or brewery by-product required for experiments; cold-chain (freezer) is used to preserve samples at low temperatures before or after processing to prevent degradation or microbial growth, and crop residue types (CRT) were used.

Experimental design and treatments allocation

This research has an experimental design with two main factors and fifteen treatment combinations (3 crop residue type (CRT) × 5 fermentation period (FP)) to examine the effect of brewery yeast in combination with three crop residues and five fermentation period (0, 3, 6, 9, and 12 days) on nutritional composition, in vitro digestibility (IVDMD), DM and OM contents, and organoleptic quality. This experiment has two-factorial arrangement in a completely random design (CRD). The treatment combinations were considered a 1:1 ratio of three-selected crop residue (Teff straw, maize and sorghum stover) with BSY at five different fermentation periods (0, 3, 6, 9, and 12 days) (Terefe et al., 2022). The control group was assigned as treated crop residue without fermentation. The entire experiments were conducted with five replications, and resulted 75 total observations. The crop residue was chopped at a recommendable sieve size of 2 mm by an electrical chopper machine according to method of Terefe et al. (2022). The mixture of brewery spent yeast, and three (3) dominant crop residues treatment combinations ensiled with five different fermentation time (0, 3, 6, 9, and 12 days) with five replications and which resulted 75 total observations. Polyethylene materials were chosen for the anaerobic ensiling process due to its suitable mechanical characteristics, low costs, and availability.

Table 1 – Completely Randomized Design experimental layout and treatment combinations.

Crop residue type (CRT) \ Fermentation period/days	0	3	6	9	12
Teff straw (TS)	TS01+BSY	TS31+BSY	TS61+BSY	TS91+BSY	TS121+BSY
	TS02+BSY	TS32+BSY	TS62+BSY	TS92+BSY	TS122+BSY
	TS03+BSY	TS33+BSY	TS63+BSY	TS93+BSY	TS123+BSY
	TS04+BSY	TS34+BSY	TS64+BSY	TS94+BSY	TS124+BSY
	TS05+BSY	TS35+BSY	TS65+BSY	TS95+BSY	TS125+BSY
Maize stover (MS)	MS01+BSY	MS31+BSY	MS61+BSY	MS91+BSY	MS121+BSY
	MS02+BSY	MS32+BSY	MS62+BSY	MS92+BSY	MS122+BSY
	MS03+BSY	MS33+BSY	MS63+BSY	MS93+BSY	MS123+BSY
	MS04+BSY	MS34+BSY	MS64+BSY	MS94+BSY	MS124+BSY
	MS05+BSY	MS35+BSY	MS65+BSY	MS95+BSY	MS125+BSY
Sorghum stover (SS)	SS01+BSY	SS31+BSY	SS61+BSY	SS91+BSY	SS121+BSY
	SS02+BSY	SS32+BSY	SS62+BSY	SS92+BSY	SS122+BSY
	SS03+BSY	SS33+BSY	SS63+BSY	SS93+BSY	SS123+BSY
	SS04+BSY	SS34+BSY	SS64+BSY	SS94+BSY	SS124+BSY
	SS05+BSY	SS35+BSY	SS65+BSY	SS95+BSY	SS125+BSY
Total	15	15	15	15	15

BSY = Brewery spent yeast, CRT= crop residue type, TS = Teff straw.

Data collection

The data was collected from experimental trails of treated crop residue with BSY. The data were collected from the brewery-spent yeast in combination with crop residue effects on in vitro digestibility (IVDMD and IVOMD), DM contents, NDF, ADF, ADL, EME, CP, OM contents, ash, and organoleptic quality.

1. In vitro dry matter digestibility (IVDMD) and in vitro organic matter digestibility (IVOMD)

- Determined using the Tilley and Terry (1963) two-stage technique.
- First stage: Incubation of samples with rumen fluid for 48 hours at 39°C.

- Second stage: Treatment with pepsin and hydrochloric acid (HCl) to simulate post-ruminal digestion.

2. Dry matter (DM) content

- Samples were dried in a forced-air oven at 105°C for 24 hours until a constant weight was achieved.

3. Neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL)

- Determined using the Van Soest et al. (1991) detergent analysis system.
- NDF and ADF were extracted with neutral and acid detergent solutions, respectively, while ADL was measured after treating ADF with 72% sulfuric acid.

4. Estimated metabolizable energy (EME)

- Calculated using the formula: EME (MJ/kg) = 0.0157×IVDMD (%)

5. Crude protein (CP) content

- Determined using the Kjeldahl method to measure nitrogen content, followed by conversion to CP using the factor 6.25.

6. Organic matter (OM) content and ash

- Ash was determined by igniting samples in a muffle furnace at 550°C for 6 hours, and OM was calculated as: OM=DM−Ash.

Procedure for data analysis

Data preparation: The raw laboratory data were organized in a structured format, ensuring that all variables (organoleptic evaluation, fermentative characteristics, chemical composition, and in vitro digestibility) were correctly labeled. Data were checked for completeness, consistency, and possible outliers before analysis.

Experimental design and model specification

A. Completely Randomized Design (CRD) was used with a 3 × 5 factorial arrangements to assess the effects of crop residue types (Teff straw, maize stover, and sorghum stover) and fermentation periods (0, 3, 6, 9, and 12 days). Where the model was specified as follows: $yijk = \mu + \tau i + \beta j + (\tau\beta)\ ij + \epsilon ij$k

Where $yijk$ is a response variable (organoleptic evaluation, fermentative characteristics, chemical compositions, in-vitro digestibility); μ is an overall mean; τi^{th} is the effect of crop residue types (Teff straw, maize, sorghum stover); βj^{th} is the effects of fermentation period (0, 3, 6, 9, and 12); $(\tau\beta)j^{th}$ is the effect of the interaction between i and j; ϵijk^{th} is the random error.

Statistical analysis

The laboratory data were subjected to analysis of variance using the general linear model (GLM) procedures of R software (Version 4.3.3). Mean Separation was performed using the least significant difference (LSD) at ($P \leq 0.05$). The statistical model was structured to evaluate both the fermentation effects over different durations and the baseline effects of brewery spent yeast (BSY) treatment compared to untreated residues. This approach provided a comprehensive framework for comparison.

Interpretation and reporting

Results were interpreted by assessing main effects (crop residue type and fermentation period) and their interaction effects on response variables. Significant findings were summarized in tables and figures to facilitate comparisons. Statistical assumptions (normality and homogeneity of variance) were checked to validate the results.

RESULTS AND DISCUSSION

Chemical composition of treated crop residues with BSY

The chemical composition of brewery spent yeast treated CRT ensiled under different fermentation period was presented in Table 2. Accordingly, DM content ($p < 0.01$), ash ($p < 0.001$), OM content ($p < 0.001$), and CP ($p < 0.01$) was significantly varied for the interaction of crop residue type and fermentation period. The DM, ash, OM, and CP contents increased consistently with an increase in the fermentation period. At 12 days of fermentation period, the DM contents of the Teff straw, maize stover and sorghum stover were 96.04, 95.17 and 95.4%, respectively was recorded.

Brewery spent yeast treated Teff straw, maize and sorghum stover have high DM and OM content. It was found between 89% and 94%; Teff straw tends to have a slightly higher OM content compared to maize and sorghum stover. The

DM content of the Teff straw, maize, and sorghum stover were observed in the current study slightly lower than the DM content of 96.23%, reported by Taddess et al. (2016). This suggests that both the type of crop residue and the duration of fermentation period have crucial roles in determining the moisture content retained in the treated CRT. Variations in DM content can affect the storage stability and nutritional quality of the treated CRT. In this study, with high DM content, the OM percentage often remains high, leading to a dense concentration of nutrients in the feed. This is beneficial for feeding livestock as it provides more energy and nutrients per unit of feed.

The CP content of Teff straw, maize stover, and sorghum stover treated CRT was improved due to the addition of BSY; thereby CP content was increased as compared to the untreated group. The CP content of crop residue types treated with BSY was significantly ($p < 0.05$) difference. This is in agreement with the finding of Abebaye et al. (2020), who reported that green maize stover treated with additives was higher CP content from than the control group. In line with the findings of Bilal (2009), who reported that adding molasses and corn to grass silage and inoculating coffee husks with effective microorganism produced a higher CP content than the control.

The ash content, which indicates the total mineral content, also showed significant variation ($p < 0.001$) among crop residues and fermentation period. In line with the current findings Yonatan et al. (2011), reported that coffee husk ensiled with additives for varying fermentation times had an increase in ash content. In contrast, the ash content did not exhibit a significant ($P > 0.05$) difference change across all treatments, according to the findings published by Abebaye et al. (2020). This indicates that the mineral composition of the treated CRT is influenced by both the nature of the crop residue and the fermentation duration. Higher ash content may reflect greater mineral retention or contamination of soil during ensiling.

The current result showed that, fermentation period increases, the DM contents of crop residues were slightly increase. During fermentation, microorganisms such as bacteria and fungi break down the complex carbohydrates, proteins, and other organic compounds present in the crop residues. This breakdown can lead to the production of metabolites like organic acids, which might result in a slight reduction in the moisture content of the material. The ash and CP content of brewery-spent yeast treated CRT were increased with increasing fermentation period runs from zero to twelve days. The organic matter contents of brewery-spent yeast treated crop residues was increased as the fermentation period increased. The organic matter and dry matter contents of treated crop residues types are related each other's. Some changes in the organic matter content were also influence the total dry matter content.

Table 2 - Chemical composition of treated CRT with brewery-spent yeast (DM basis).

Treatments \ Contents		DM	Ash	OM	CP
Teff straw (TS)	0	90.42^{e}	6.66^{fg}	92.76^{abc}	6.31^{fg}
	3	91.97^{d}	6.68^{fg}	93.08^{ab}	8.32^{ef}
	6	93.67^{c}	6.91^{fg}	93.32^{ab}	8.68^{ef}
	9	94.32^{b}	7.25^{efg}	93.34^{ab}	9.06^{d}
	12	96.04^{a}	8.27^{bcdef}	94.14^{a}	9.22^{d}
Maize stover (MS)	0	91.75^{d}	8.91^{bcde}	90.22^{fg}	8.95^{de}
	3	92.91^{d}	9.34^{abc}	90.25^{fg}	11.62^{c}
	6	93.02^{c}	9.78^{ab}	90.66^{efg}	15.98^{b}
	9	94.02^{b}	9.76^{ab}	91.09^{cdef}	16.36^{b}
	12	95.17^{a}	10.64^{a}	91.31^{cdef}	18.32^{a}
Sorghum stover (MS)	0	90.84^{e}	7.78^{cdef}	91.79^{bcdef}	9.41^{d}
	3	92.44^{d}	7.81^{cdef}	91.94^{bcde}	11.92^{c}
	6	93.47^{c}	8.06^{cdef}	92.19^{bcde}	16.28^{b}
	9	94.67^{b}	8.20^{bcdef}	92.22^{bcde}	16.66^{b}
	12	95.41^{a}	9.09^{abcd}	92.50^{abcd}	18.62^{a}
	SEM	0.141	0.328	0.328	0.832
	P-value	0.01	0.001	0.001	0.01

$^{a\text{-}g}$ Means with in a column with different superscripts differ at $p < 0.05$. CRT= crop residue type; FP= fermentation period; DM= dry matter; OM= organic matter; CP= crude protein; SEM= standard error of the mean.

Fiber composition of treated crop residue with BSY

The neutral detergent fiber, acid detergent fiber and acid detergent lignin of brewery-spent yeast treated crop residue types that ensiled under different fermentation period were presented in Table 3. The brewery spent yeast treated CRT of NDF content ($p < 0.01$), ADF ($p < 0.001$) and ADL ($p < 0.01$) were significantly varied for the interaction of crop residue type and fermentation period.

Table 3 - Fiber composition of brewery-spent yeast treated crop residue (DM basis).

Treatments \ Contents		NDF	ADF	ADL
Teff straw (TS)	0	72.32^{a}	46.20^{cdefg}	7.78^{ab}
	3	71.02^{a}	45.67^{fg}	7.73^{ab}
	6	70.65^{ab}	45.14^{fg}	7.60^{abc}
	9	69.34^{ab}	45.87^{defg}	7.56^{abc}
	12	68.86^{ab}	44.09^{fg}	6.45^{defg}
Maize stover (MS)	0	57.38^{defg}	46.52^{cdef}	6.42^{defg}
	3	54.65^{efgh}	46.21^{cdefg}	5.94^{efgh}
	6	53.98^{fgh}	45.85^{defg}	5.90^{efgh}
	9	53.49^{gh}	45.76^{efg}	5.81^{efgh}
	12	51.36^{h}	43.06^{g}	5.25^{h}
Sorghum stover (MS)	0	62.13^{cd}	52.26^{b}	6.48^{defg}
	3	61.75^{cd}	51.92^{b}	5.86^{efgh}
	6	61.69^{cd}	51.36^{b}	5.68^{fgh}
	9	59.71^{de}	49.46^{bc}	5.55^{gh}
	12	58.65^{def}	49.07^{bcde}	5.29^{h}
	SEM	0.993	0.65	0.204
	P-value	0.01	0.001	0.01

$^{a-h}$ Means with in a column with different superscripts differ at $p < 0.05$ CRT= crop residue type, FP= fermentation period, NDF= neutral detergent fiber, ADF= Acid detergent fiber, ADL= Acid detergent fiber, SEM= standard error of the mean.

The NDF content, indicative of the cell wall components such as hemicellulose, cellulose, and lignin, showed significant variation ($p < 0.01$) due to the interaction of crop residue type (TS, MS, and SS) and fermentation period. The value of BSY treated CRT was lower than the control grouped. The value of neutral detergent fiber was higher for Teff straw than maize and sorghum stover. The value of NDF, ADF and ADL was declined as the fermentation period increased. Among the crop residue types, the lower value of neutral detergent fiber, acid detergent fiber and acid detergent lignin was recorded for maize stover than sorghum stover and Teff straw. The observed decline in NDF (Neutral Detergent Fiber), ADF (Acid Detergent Fiber), and ADL (Acid Detergent Lignin) values as the fermentation period increased suggests that fermentation improves the in vitro digestibility of crop residues by breaking down fiber components. This can enhance the nutritional quality of the residues for ruminants. The decrease in NDF and ADF suggests an improvement in the potential in-vitro digestibility of the crop residues over the fermentation period. In line with Abebaye et al. (2020) found that during all fermentation periods, silage treated with molasses and ensiled for six weeks had significantly lower levels of NDF ($p < 0.05$) value than the control. Similarly, Hosseini et al. (2019), the alfalfa, barely and corn silages that were not treated had higher levels of NDF than silages that had additive treatment. This shows that, fermentation generally reduces NDF content, improving forage nutritional value, digestibility, and intake and increase fiber breakdown. Lower values of these fiber components typically reflect better in vitro digestibility and higher nutrient availability for animals, especially in ruminant diets.

The ADF content, which includes cellulose and lignin, significantly ($p < 0.001$) varied with the interaction of crop residue type and fermentation period. The ADF value from the present study was lower 12th day that zero days of FP. NDF and ADF are essential for balancing the nutritional needs of ruminants, promoting rumen health, and optimizing overall feed efficiency. Proper management of these fiber components leads to better performance, enhanced energy utilization, and improved long-term health in animals (Carrillo-Díaz et al., 2022).

Acid detergent fiber founds between the ranges of 43.0-56.2%DM and the fermentation period increase the contents of ADF also decrease. The lower value was observed during the 12 days of FP with inclusion of brewery-spent yeast. Similarly, in a related study by Yadessa et al. (2023), reported that, a decreasing in ADF values with the level of BSY increases in the silage materials, it was found to be declining, with the lowest ADF value recorded at 20 and 30% of the BSY inclusion level in the fourth and sixth weeks of the fermentation period. On the other hand, Kamphayae et al. 2016) reported reducing trend of ADF values with the level of brewery spent yeast increases in the silage ingredients. This indicates lower ADF values indicate a higher proportion of digestible nutrients in the feed. This means that animals can more efficiently break down and absorb nutrients like carbohydrates and proteins, leading to better growth and productivity.

In vitro digestibility and energy estimation of treated crop residue with BSY

In vitro dry matter and organic matter digestibility of brewery spent yeast treated CRT was significant ($p < 0.001$ and $p < 0.001$) varied respectively and presented in table4. The value IVDMD and IVOMD was statistically significant for brewery spent yeast treated CRT. The metabolized energy of brewery spent yeast treated crop residue type was significantly ($p < 0.001$) varied and presented in Figure 2. The value of estimated metabolized energy (EME) was increased as the fermentation period increased. The estimated metabolized energy of treated Teff straw, maize, and sorghum stover was higher than the day zero. At 12 days of fermentation period, the value of Teff straw, maize and sorghum stover were 7.9, 10.64, and 9.64 MJ/kg respectively.

Table 4 - IVDMD and IVOMD of brewery-spent yeast treated crop residue.

Treatments \ Digestibility parameters (DM basis)		IVDMD	IVOMD
Teff straw (TS)	0	53.75^{h}	47.52^{f}
	3	54.45^{h}	47.71^{f}
	6	55.05^{gh}	48.61^{f}
	9	55.16^{fgh}	48.74^{f}
	12	55.73^{efgh}	49.25^{f}
Maize stover (MS)	0	61.30^{bcd}	62.87^{abc}
	3	61.77^{bc}	63.46^{abc}
	6	62.75^{ab}	63.49^{abc}
	9	62.79^{ab}	64.03^{ab}
	12	65.17^{a}	66.48^{a}
Sorghum stover (SS)	0	58.31^{defg}	57.23^{de}
	3	58.48^{cdef}	58.48^{d}
	6	59.74^{bcd}	58.52^{d}
	9	59.00^{cde}	59.57^{cd}
	12	61.46^{bcd}	60.33^{bcd}
	SEM	0.66	0.77
	P-value	0.001	0.001

[a-h] Means with in a column with different superscripts differ at $p < 0.05$, CRT= crop residue type, FP= fermentation period, IVDMD=*In vitro* dry matter digestibility, IVOMD= *In vitro* organic matter digestibility, SEM= standard error the of mean.

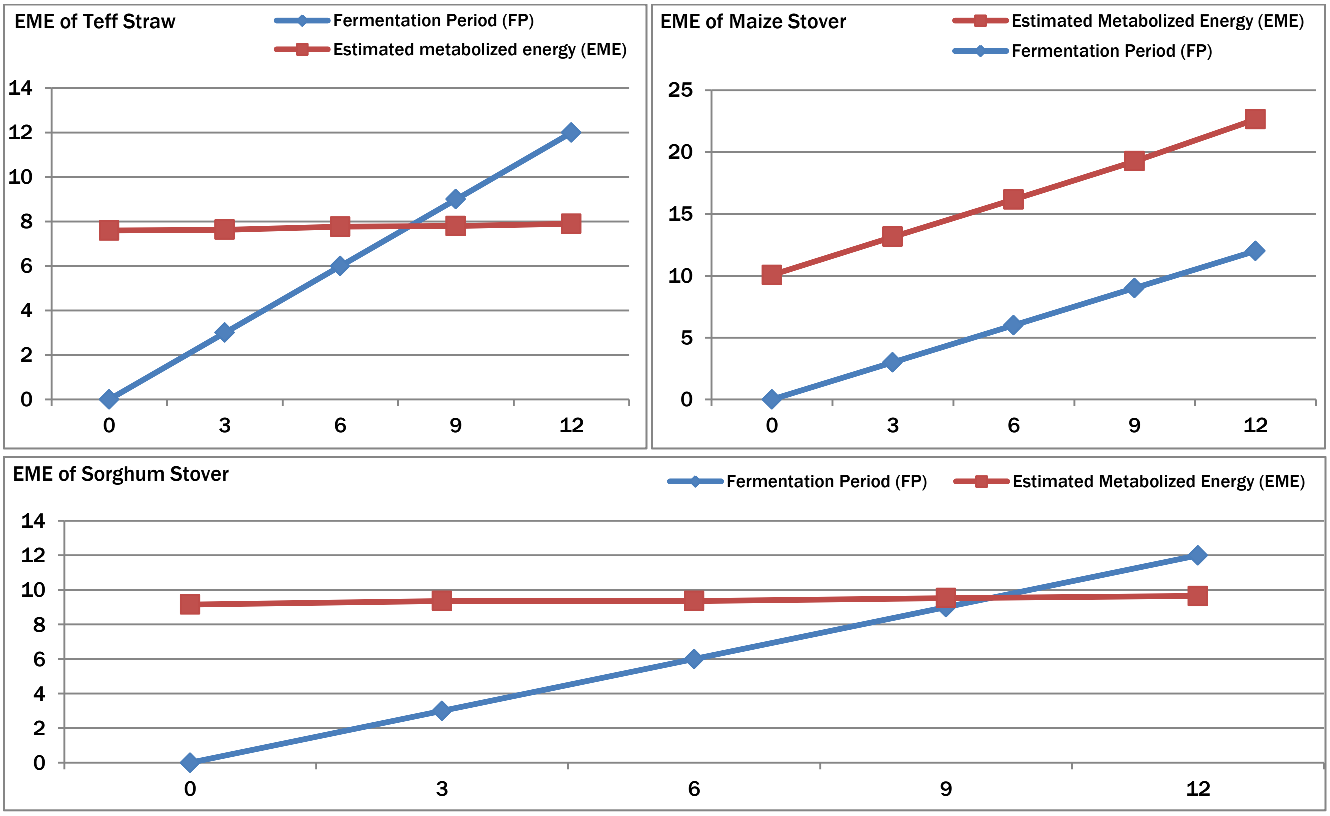

Figure 2 - Estimated metabolized energy of treated crop residue with brewery-spent yeast

The maize stover had a metabolizable energy of 10.0 MJ/kg at day zero. The ME initially day zero (10.06 MJ/kg), then increased progressively, reaching a peak of 10.64 MJ/kg at 12th days of fermentation period. Overall, maize stover showed the highest ME values across all fermentation periods compared to Teff straw and sorghum stover. The value of ME at day zero was 9.16 MJ/kg, but then gradually decreased with extended fermentation, reaching 9.65 MJ/kg at day 12.

The EME, IVDMD and IVOMD of brewery spent yeast treated CRT in the present study was higher at longer fermentation period than zero day (control). Comparatively slightly higher EME, IVDMD and IVOMD values in the present study reported for 12th days of fermentation period. In a similar investigation, Kamphayae et al. (2016) found that adding up to 30% more BSY to cassava pulp significantly increased the silage materials of IVDMD, IVOMD and EME within 4 weeks of the start of the ensiling period. This is crucial for assessing the energy and digestibility value of the treated CRT, which is a key factor in animal performance. Higher digestibility ensures that the animals can extract more nutrients from the feed, improving their growth, milk production, and overall health. Enhanced digestibility and energy content of feed can lead to better-feed conversion ratios, reduced feeding costs, and improved sustainability in livestock production systems. Abebaye et al. (2020), also reported that the IVOMD (*in vitro* organic matter digestibility) and ME (MJ/kg) content was higher in green maize stover silage, which was treated with molasses and fermented for six to eight weeks of the than the control group. Other study by Kitaw et al. (2018), denoted the reduction in DM digestibility and significant losses in nutritional components may be attributed because of the aerobic deterioration of treated CRT material stored at high temperatures for extended period.

CONCLUSION

Results indicated that the fermentation time significantly affected the chemical composition of the treated crop residues. The study found that as fermentation time increased, the contents of dry matter, organic matter, and crude protein rose. Conversely, the levels of neutral detergent fiber, acid detergent fiber, and acid detergent lignin decreased over time, suggesting improved digestibility. Digestibility rates for dry matter and organic matter were notably higher compared to untreated residues. The findings highlight that the use of brewery yeast can enhance the nutritional quality of crop residues, making them more suitable for livestock feed. Therefore, based on the finding of this research the following recommendations are given: A) Broad awareness should be created among smallholder farmers about the significance role of brewery spent yeast treated crop residues; B) In terms of nutritional value, organoleptic quality, and digestibility values and wisely utilization of the bulk available crop residue, has paramount significant contribution to the feed cost reduction.

DECLARATION

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Data availability

The data that support the study findings are available from the corresponding author upon request.

Author contribution

M. Getachew: Formal analysis, data curation, investigation, software, supervision, validation, visualization, writing original draft, writing reviewing and editing, methodology; T. Amare: Conceptualization, funding acquisition, project administration, supervision, validation, methodology, writing original draft; E. Yimer: Conceptualization, funding acquisition, project administration, supervision, methodology, writing original draft

Consent to publish

All participants have consented to the submission of the research article to the journal.

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Ethics committee approval

The experiment was approved by the Ethics Committee of the Holeta Agricultural Research Institute.

Competing interests

There are no disclosed conflicts of interest for the writers. There are no financial interests to disclose, and all co-authors have reviewed and approved the manuscript's contents.

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