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Research Article

An Assessment of the Status and Factors Influencing Utilization of Brewery Byproducts as Feed to Dairy Cows Under Smallholder System in Northern Tanzania

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Abstract

A cross-sectional survey study was conducted in Arusha City and Hai districts in northern Tanzania to assess the status and factors influencing the usage of brewery byproducts as feed for dairy cows. A total of 110 respondents were interviewed using a structured questionnaire. The information collected included gender, educational background, farm size, main occupations, dairying experience, types of concentrates fed to dairy cows and factors affecting the use of brewery byproducts as feed to cows. The body weights of 76 selected cows were estimated using heart girth tape, along with secondary data collected from the farm record books on milk yield. Key informant interviews were made with industry supervisors in two beer processing industries in the two locations. Samples of different types of brewery waste and concentrates used in the study area were collected and chemically analysed, and the two-stage in vitro digestibility was estimated. The study found that farmers with formal education, dairy experience of 10 to 20 years, small farm sizes and herd sizes of more than 15 cows had a greater ($P<0.05$) likelihood of using brewery byproducts as a supplement to dairy cows. The values of crude protein (23.0%, CP) and nitrogen detergent fibre (51.8%, NDF) contents of wet spent grain byproduct (WSGB) were higher ($P<0.05$) compared to those of concentrates (12.5 and 28.8%, respectively) commonly used in the study area. The values of in vitro dry matter (63.6 - 65.1%, INVDMD) and organic matter (60.0 - 61.5 INVOMD) digestibility of WSGB were lower ($P<0.05$) than those of common concentrates with 81.5 and 80.4% for INVDMD and INVOMD, respectively. Cows supplemented with brewery waste had higher ($P<0.05$) values of milk yield (11.7 litres/cow) and body weight (363.5 kg) compared with those supplemented with common concentrates (9.4 and 341.6, respectively). The usage of brewery byproducts was reported to be influenced by insufficient supply in Hai District (58.82%), while in Arusha city, price fluctuations (29.4%), capital requirements (20.6%) and transportation (8.8%) were the most limiting factors. In conclusion, brewery byproducts are potential feed resources for improving milk production from the dairy cows under a smallholder farming system in Northern Tanzania. Further assessments of the economic profitability of utilizing brewery byproducts as feed supplements for lactating dairy cows managed by smallholder dairy farmers are recommended.

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Keywords

Dairy Cattle Feeds, Nutritive Values, Milk Yield, Herd Structure, Location, Farm Size, Socioeconomic Factors

1. Introduction

The growth of dairy production in urban and peri-urban areas of northern Tanzania was triggered by among other factors, the increasing demand for dairy products resulting from elevated rural-to-urban migration. The sector is constrained by feed shortages stemming from various factors, notably the rising number of small dairy farms, competition for feed between humans and animals, limited land for grazing and pasture cultivation, and the high cost and insufficient supply of traditional feed sources [1]. Furthermore, improvements in dairy cattle diets and general animal performance have led to important technological improvements aiming at increasing the concentration of nutrients in cow diets. This has improved the integration of crops and livestock by feeding remains of agricultural processing industries to animals owing to their nutrients [2]. The scenario is attributed to the fact that the dependence of farmers on cereals and grain sources as feed to dairy cows is associated with increased expenses due to competition between the sector and humans for food [3]. This necessitates the exploration of additional sources of feed materials from agricultural processing industries that use a huge volume of grains and cereals, for instance, the brewing industry, which yields huge amounts of brewery by-products.

The bulky raw materials commonly used for brewing include barley, sorghum, and maize [4]. The brewing process generates a significant amount of by-products, of which 85% of raw materials are estimated to comprise brewery byproducts [5]. These byproducts are equivalent to 14-20 kg of wet spent grains byproducts (WSGB) for every hectoliter of beer produced. The (WSGB) is composed of grain residue fractions such as husk, pericarp, and fragments of endosperm [6]. The investments made by Tanzania Breweries Limited (TBL) in Arusha and Serengeti Breweries in Kilimanjaro regions have resulted in the availability of brewery byproducts, which could be used in livestock as feed resources [7]. According to [4], brewing industries in Northern Tanzania produce approximately 36 million litres of beer per month. This is equivalent to an estimated amount of 5,016.2 to 7,166 tons of brewery byproducts monthly, highlighting the potential for using the byproducts in agricultural applications specifically as livestock feed.

The change in beer type in brewery industries employs different types of ingredients in beer making, which could affect the composition of the brewery byproducts produced and the fluctuation of nutritional values to sustain cattle demand [8]. Wet spent grain brewery byproduct (WSGB) and Brewery Yeast byproduct (BYB) represent promising resources for livestock feed ingredients. According to [9], the WSGB has a crude protein range from 24 to 31% CP and an energy content of 14.8 MJ ME/kg DM. In addition, the byproducts contain a significant amount of essential minerals and vitamins [10]. The BYB contains CP ranging from 43 to 49% and carbohydrates at 31.6% dry matter [11]. Feeding of alcohol byproducts to dairy cattle has a characteristic of altering microbial community that increases the fermentation process, hence raising the volatile fatty acids (VFAs) in the rumen that could positively favour milk quality attributes, such as milk fat [12]. According to [13], crossbred Jersey dairy cows have shown increased milk yields by 1.8 kg when fed brewery byproducts over traditional compounded feeds.

Small-scale dairy farming in urban and peri-urban areas of Northern Tanzania is facing feed availability and quality challenges. The exploitation of the relationship between the use of brewery byproducts in the diets of dairy cows and production performance, such as body weight gain, milk yield and quality are essential for validating its use as a sustainable feed alternative. Similarly, some factors, such as demographic, socioeconomic and herd structure dictate the decisions of smallholder dairy farmers regarding the usage of dairy technologies [14-16]. Nevertheless, there is limited information on the factors affecting the usage of brewery byproducts and their influence on animal performance. The information is required to provide an understanding of the primary mechanisms important for developing sustainable feed availability and establishing feeding strategies to optimize productivity and minimise nutrient loss and environmental degradation. The present study aimed to assess the status and factors influencing the utilization of brewery byproducts as animal feed supplements for dairy cows kept under smallholder dairy farms in northern Tanzania.

2. Materials and Methods

2.1. Selection and Description of the Study Area

The study was conducted in Arusha City and Hai district, Northern Tanzania (Figure 1). The criteria for selecting the study site were based on the fact that the area is among the highly milk-producing regions, the availability of smallholder dairy farms, and dairying systems, where households keep at least one crossbred lactating dairy cow and dry cow or in-calf

heifer. Arusha City is the main capital of the Arusha region, located at an elevation of 1500 meters above sea level, latitude 3 °21'43.68"S and longitude 36 °42'33.35"E. The average annual temperature is between 21 ℃ and 24 ℃, with an average annual rainfall range from 800 to 1000 mm. The Hai District Council is one of the districts in the Kilimanjaro region, located south of Mount Kilimanjaro, at a latitude of 2 °50'3 °29" S and longitude of 30 °30'37 °10" E. The district receives an average of 521 mm of rainfall, and features a bimodal rainfall pattern, with long rains from March to June and short rains in November and December. It experiences an average annual temperature of 23.3 ℃. The two districts have access to brewery byproducts from the beer-producing industries present in Arusha City and Moshi Town. The two districts were involved in the Enviro-cow project, which was a research initiative aimed at reducing greenhouse gas emissions and improving the environmental efficiency of dairy cattle in sub-Saharan Africa.

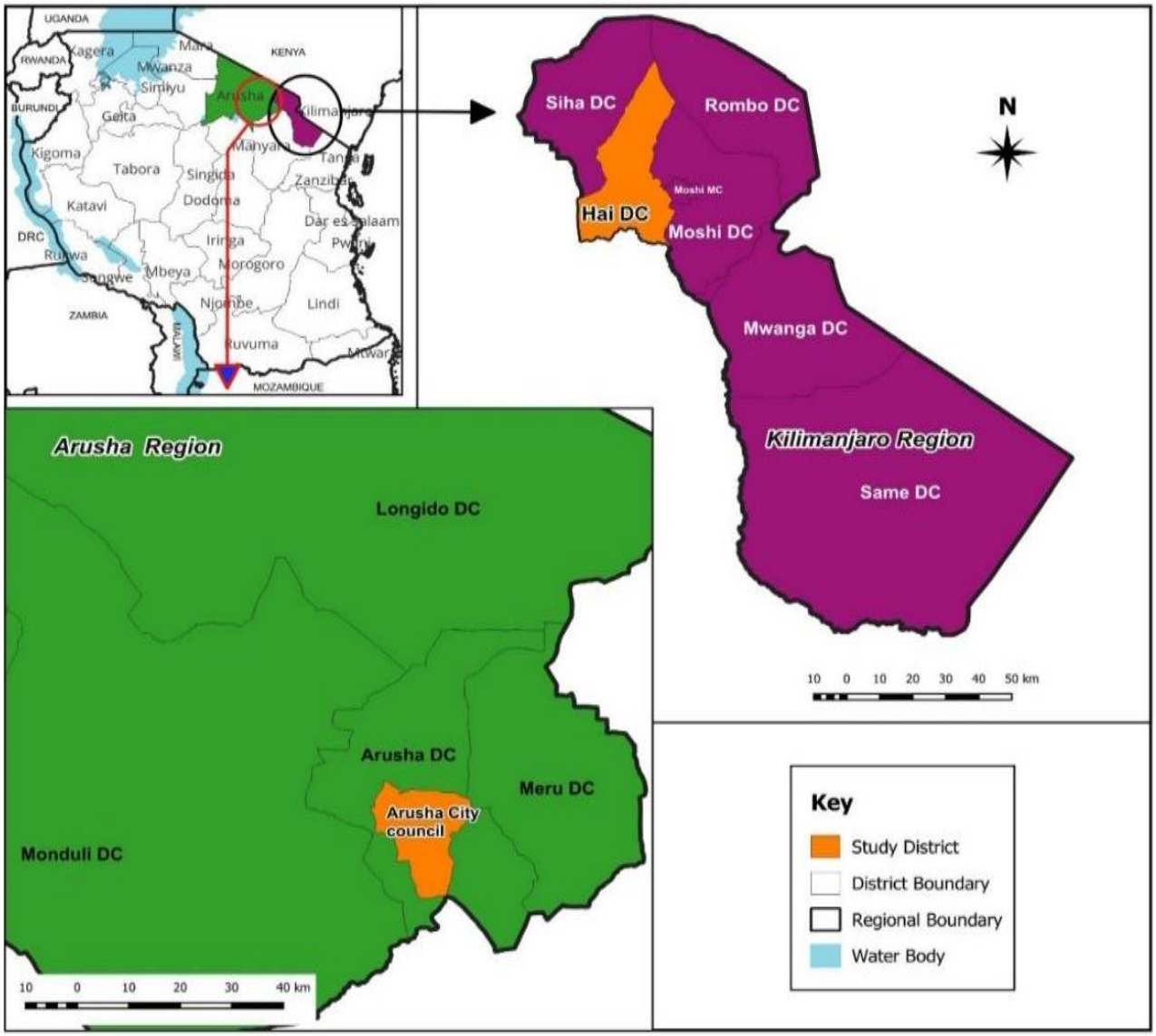

Figure 1. *A map showing the study areas of Arusha City and Hai district councils in northern Tanzania.*

2.2. Nature of the Study

The study involved key-informant and household interviews, field observations, direct measurements, collection of secondary data and feed samples.

2.2.1. Key Informant and Household Interviews

The key informant interviews involved the plant supervisors from two brewing industries, referred to as Industry A and Industry B, which are operating in the two study locations. Checklist questions were used, which focused on the primary categories and amounts of raw materials used by the indus-

tries and the types and amounts of by-products produced. Other information gathered from the key informants included the uses and the main buyers of the brewery byproducts from their industries.

The household interviews were performed to obtain both quantitative and qualitative data from the household heads. Before the selection of respondents, some discussions were held between the research agents of the Enviro-Cow project and extension officers in the two districts to establish the list of the farmers who were involved in the Enviro-Cow project. The number of respondents for the household interviews was determined following purposive and simple random sampling methods described by [17, 28]. The selected respondents were members of the Enviro-Cow project practicing intensive or zero-grazing production systems and supplementing dairy cows with concentrates, such as dairy meals or brewery by-products. A total population of 130 households was identified, 60 households from Arusha City and 70 from the Hai district council. Using a random sampling procedure [18], a sample of 110 households, 50 from Arusha City and 60 from the Hai district council were selected for the interview.

A cross-sectional design was employed to collect information using a structured questionnaire, which was developed and posted in the open data kit platform, a software installed in Android devices to enable the collection of data under field conditions and directly sent to the main server. This allowed capturing responses on the handheld Android smartphones. The questionnaire was pre-tested before the household interviews using a random sample of 15 smallholder dairy farmers from each district. The questionnaire was written in English, however, during the interviews it was translated into Swahili, a common language of the farmers, to facilitate communication and ensure precise data collection. The interviews were carried out for a period of three months, from February to April 2024. The type of information collected included gender type, education level, size of the farm used for dairy production, number of animals, and herd composition. Other information included experience in dairy farming, common types of concentrates, including brewery byproducts used to supplement dairy cows, the source of the brewery byproduct, main occupations, and major challenges encountered in using brewery byproducts.

2.2.2. Collection of Cow Data

A total of 76 lactating dairy cows, 36 from Arusha City and 40 from Hai district were selected from the identified households. The criteria used in selecting the cows included being healthy, within one and two lactation stages, and being supplemented with concentrates, either dairy meal, homemade concentrate, or brewery wastes. The dairy cows were fed on locally available forage materials and supplemented with either brewery byproducts, dairy meal or homemade concentrate diet based on the farm management practice. Based on the type of supplementation, selected cows were grouped into two categories that are cows supplemented with brewery byproduct and those supplemented with other common concentrates. The body weights of the cows were estimated using heart girth (HG) that is measuring the body circumference behind the front shoulder at the fourth rib, posterior to the front leg using a weighing band. The live weight (LW) of a cow was derived following the equation described by [19].

Records of milk yield from the selected cows were searched from the server of the Enviro-cow project and supplemented with records from the books kept by the farmers from September 2023 to April 2024. Samples of milk from all the selected cows were collected in vial of 50 ml and preserved in a cold chain for subsequent analyses.

2.2.3. Collection and Preparation of Samples of Brewery Byproducts

Concurrent with the household surveys, the types of supplements given to lactating dairy cows in each household were identified from the feeding troughs and representative samples were collected from the feed store of a respective farmer. Thirty-nine (39) samples of wet spent grain byproduct (WSGB) and 12 samples of liquid brewery yeast byproduct (LBYB) were collected from the farms of the respondents who used brewery byproducts as supplements to lactating dairy cows and a total of 32 common concentrates were collected from surveyed households that were not using brewery byproduct in the study area. Four (4) representative samples of dry brewery yeast byproduct (DBYB) were collected from the beer processing industries, following two visits, separated by one-month intervals made on the industries. The samples were collected in different packaging materials, each weighing approximately 1 kilogram. The dry samples were taken in envelopes, whereas the wet samples were placed in waterproof zip-top plastic bags and stored frozen at the Tanzania Veterinary Laboratory Agency (TVLA)-Arusha. The frozen samples of WSGB and LBYB were thawed in a water bath at 39-40 ℃ following the steps outlined by [20]. In determining the dry matter (DM) contents of the brewery byproducts, the LBYB underwent rotary evaporator extraction described by [21] to freeze-dry the samples at the Laboratory of Veterinary Medicine in the Sokoine University of Agriculture (SUA). The samples of WSGB and BYB were oven-dried to determine the dry matter contents according to the procedures of AOAC [22].

2.3. Laboratory Analyses

The contents of crude protein (CP), neutral detergent fibre (NDF), and acid detergent fibre (ADF) in the samples of WSGB and BYB were determined using the Near-infrared spectroscopy (NIRS) methodologies as outlined by [23]. The values of the *in vitro* dry matter (INVDMD) and organic matter (INVOMD) digestibility of the samples were determined using the two-stage technique [24]. The metabolizable energy (ME MJ/kg DM) contents of the samples were pre-

dicted according to [25] for ruminant animals. The attributes of milk quality are percentages of fat, protein, lactose, solids and solid not fat (SNF) were analyzed using Lactoscope 300^{MT} at the laboratory of the National Artificial Insemination Centre (NAIC-Arusha), adhering to established protocols by [26].

2.4. Statistical Data Analysis

The data collected were managed, encoded, and cleaned using computerized Excel software. The Statistical Package for Social Sciences (SPSS) software [27] was employed to analyse the categorical variables (demographic and socio-economic factors). Descriptive statistics were conducted by calculating frequencies and proportions in the cross-tabs approach using the dependent variable (locations and brewery by product usage) and independent variables (demographic and socioeconomic factors. The chi-square test (x^2) was used to measure the differences between the categorical variables. Logistic regression employed a multivariate model to identify the usage of brewery byproducts in the two study areas by pooling them together, linked with categorical variables that are demographic and socioeconomic factors where the dependent variable was the usage of brewery byproducts and the independent variables were categorical variables. Variables significant in univariate analysis (P≤0.05) were included in the multivariable model. The entry probability was set at a confidence interval (CI) of 95% and the usage was examined in coefficient and adjusted odds ratio. The coefficient value was the parameter showing the change in the odds of the outcome occurring for each unit increase in the predictor variables. The odds ratio (OR) was the parameter, which was used to assess the relationship between a predictor or independent variable and a binary outcome or dependent. The Hosmer- Lemeshow goodness of fit model was tested using the likelihood ratio at 5%. The general linear model of JMP® pro 18-2024 of statistical analyses software (SAS) was used to analyze the continuous variables (nutritional values, body weight, and milk production parameter), where the T-test was used to assess the differences between the variables. The differences between means were considered significant at (P≤0.05).

3. Results

3.1. Demographic Characteristics of the Respondents

The frequencies of the demographic information of the respondents in Arusha City and Hai district are presented in Table 1. In both locations, a greater number of respondents were males compared with females. The number of respondents who had attained at least a primary and secondary level of education was higher in Hai district than in Arusha City. However, those with tertiary education levels were higher in Arusha City compared to those from Hai district. The number of respondents with land sizes of less than 1 acre for dairy farming was higher in Arusha City than in Hai district, while those with farm sizes of 1 to 5 acres were more prevalent in Hai district than in Arusha City. A greater number of respondents with 11 to 20 years and over 20 years of experience in dairying were found in the Hai district compared to those from Arusha City. However, respondents with less experience of 1 to 10 years were more in Arusha City than those from Hai district. Regarding main occupation, respondents involved in dairy farming were more numerous in Arusha City than in the Hai district, while those engaged in mixed farming were predominantly in the Hai district.

Table 1. *Frequencies of the demographic information and farm characteristics of respondents in Arusha City and Hai districts.*

Attribute	Response	Arusha city	Hai district	Total
	No. of respondents	**50**	**60**	**110**
Household Gender	Male	38 (76)	43 (72)	81 (73.64)
	Female	12 (24)	17 (28)	29 (26.36)
Education background	No formal school	9 (18)	1 (2)	10 (9.09)
	Primary	11 (22)	33 (55)	44 (40)
	Secondary	10 (20)	15 (25)	25 (22.73)
	Tertiary	20 (40)	11 (18)	31 (28.18)
Farm size for dairy farming	<1 acre	39 (78)	42 (70)	81 (73.64)
	1 to 5 acres	11 (22)	18 (30)	29 (26.36)
Experience (years)	1 to 10	18 (36)	9 (15)	27 (24.55)

Attribute	Response	Arusha city	Hai district	Total
	No. of respondents	50	60	110
Herd size (cows)	11 to 20	20 (40)	29 (48.33)	49 (44.55)
	>20	12 (24)	22 (36.67)	34 (30.9)
	1 to 10	28 (25.45)	31 (28.18)	59 (53.64)
	11 to 15	6 (5.45)	11 (10)	17 (15.45)
	>15	16 (14.54)	18 (16.36)	34 (30.91)
Main occupation	Dairy farming	29 (58)	33 (55)	62 (56.36)
	Mixed farming	21 (42)	27 (45)	48 (43.64)

In this and subsequent tables, N represents frequencies, Values in brackets are responses in %.

3.2. Responses on the Cattle Herd Structure

The responses on the classes of dairy cattle kept by respondents in Arusha City and Hai district are presented in Table 2. The mean proportions of respondents who kept lactating cows, yearlings, and calves in Arusha city and Hai district were similar (P>0.05). However, the mean percentage of respondents who kept heifers was higher (P<0.05) in Hai district than in Arusha City. In Arusha City, however, there were no respondents who kept bull cattle, whereas, in Hai district, 23 percent of the respondents had bulls.

Table 2. *Responses on the herd composition of the cattle kept by respondents in Arusha City and Hai district.*

Herd composition	Arusha City N(%)	Hai district N(%)	Total	Chi-squire	P-Value
	50	60	110		
Lactating	50 (100)	57 (95)	107 (97)	2.57	0.109
Heifers	11 (22)	32 (53)	43 (39)	21.097	<0.001
Bulls	0 (0)	14 (23)	14 (13)	13.368	<0.001
Yearling	6 (12)	9 (15)	15 (14)	0.208	0.648
Calves	27 (54)	33 (55)	60 (55)	0.011	0.916

3.3. Usage of Brewery Byproducts by the Respondents

The responses on the usage of different types of brewery byproducts by respondents in Arusha City and Hai district are presented in Table 3. A higher percentage of respondents from the Hai district used brewery byproducts in dairy cattle more than those of Arusha City. Even though the usage of wet spent grain brewery byproduct (WSGB) was similar (P>0.05) in both locations, the liquid brewery yeast byproduct (LBYB) was used more (P<0.05) by the respondents in the Hai district than those in Arusha City. There were two main local brew byproducts used as animal feeds in the study area, dadi and mbege byproducts. Dadi byproducts are leftovers of a local brew made from the fermentation of maize and germinated finger millet flour, whereas Mbege byproducts are leftovers of a local brew prepared from the fermentation of ripe banana and germinated finger millet flour. Despite insignificant use of byproducts from these local brews as cattle feed, they were highly (P<0.05) used by the respondents from Arusha City (100%) and Hai district (86%) for feeding animals, such as pigs, shoats and poultry.

Table 3. The responses on the usage of different types of brewery byproducts in Arusha City and Hai district.

Variable	Arusha City N (%) 50	Hai District N (%) 60	Chi-squire	P-value
Usage byproduct	20 (40)	48 (80)	4.851	0.028
Byproduct types				
WSGB	20 (100)	39 (81.25)	1.227	0.542
LBYB	0	9 (18.75)	8.168	0.004
Usage of other byproducts	24 (48)	29 (48.3)	0.929	0.628
Other byproducts;				
Dadi	17 (34)	26 (43.3)	0.998	0.318
Mbege	12 (24)	15 (25)	0.015	0.903
Usage local brewery byproduct				
Cattle	0	3 (10.4)	2.57	0.109
Other species	24 (100)	26 (89.6)	28.671	0.004

In this and subsequent tables; WSGB-wet spent grain byproduct, BYB-Brewery yeast byproduct.

3.4. Factors Influencing the Usage of Brewery Byproducts in the Study Area

The general mean values of the odds ratio of demographic and socioeconomic characteristics of respondents in both locations on the usage of brewery byproducts as feed to dairy cattle are presented in Table 4. The respondents with formal education were more (P<0.05) likely to use brewery byproducts than those without formal education. Furthermore, respondents with greater experience in dairying for 11 to 10 years had a higher (P<0.05) likelihood of using brewery byproducts in feeding dairy cows than those with less experience. The respondents with small farm sizes of <1 acre of land had a higher (P<0.05) likelihood of using brewery byproducts than those with larger farm sizes of 1 to 5 acres. Moreover, respondents with large herd sizes of more than 15 cows were more (P<0.05) likely to use brewery byproducts compared to those with small herd sizes of 1 to 10 cows.

Table 4. Mean values of odds ratio of demographic and socioeconomic characteristics on the usage of brewery byproducts as feed supplements to dairy cattle in both locations.

Category	Variable	N (%)	Coefficient	Adjusted OR	P-Value
Education background	No formal	5 (7.9)		1	
	Formal	58 (92.1)	1.647	5.194 (1.339-20.139)	0.017
Experience (years)	1 to 10	12 (19)		1	
	11 to 20	38 (60.3)	1.258	3.517 (1.199-10.315)	0.02
	>21	13 (20.6)	-0.211	0.810 (0.253-2.588)	0.722
Farm size for dairy farming	<1 Acre	53 (84.1)	1.176	3.241 (1.10-25.71)	0.012
	1 to 5 Acre	10 (15.9)		1	
Herd size (cows)	1 to 10	31 (49.2)		1	
	11 to 15	5 (7.9)	-0.707	0.493 (0.134 - 1.810)	0.493
	>15	27 (42.9)	1.08	2.946 (1.21 - 8.96)	0.042

3.5. Industrial Production of Brewery Byproducts

Table 5 shows the amounts of cereal grain processing and the corresponding production of different types of brewery byproducts in the two beer industries, A and B, present in Northern Tanzania. The raw materials commonly used by Industry A for beer making were imported malt and locally produced sorghum, whereby malt was used in larger quantities than sorghum. In Industry B, sorghum, maize grist and Millard barley were the commonly used raw materials in beer making, whereby the bulky was sorghum. The types of brewery byproducts produced by the two industries were wet spent grain (WSGB) and dry and liquid brewery yeast byproducts, of which WSGB produced in larger quantities than those of yeast byproducts.

Table 5. *The quantities (Tones per annum) of raw materials and brewery byproducts produced by industries A and B in the study area.*

Component	Industry A	Industry B
Raw materials		
Malt	13140	0
Sorghum	2190	7500
Maize grist	0	4584
Millard barley	0	4584
Brewery byproducts (DM)		
Wet spent grain	3324.42	4847.2
Brewery yeast	160.05	185.5

3.6. Nutritional Values of the Brewery Byproducts and Common Concentrates Supplemented to Dairy Farmers

Table 6 presents the means of the nutritional values of the different types of brewery byproducts sourced from industries A and B and concentrates commonly used for supplementing cows in the surveyed households. The common concentrates had higher (P<0.05) mean value of dry matter (DM) content than the wet spent grain byproduct (WSGB) from industries A and B (*P<0.05*). The mean values of crude protein (CP), neutral detergent fibre (NDF), and acid detergent fibre (ADF) contents of WSGB from industries A and B were higher (*P*<0.05) compared to those of common concentrates. However, the mean values of in vitro DM (INVDMD) and organic matter (INVOMD) digestibility and metabolizable energy (ME) contents of the WSGB from both industries A and B were lower (P<0.05) compared with those of common concentrates. The mean value of DM content of the brewery yeast byproduct (BYB) of samples collected from Industry A was higher (*P*<0.05) than that from Industry B. The mean value of CP of the sample of BYB from Industry A was lower (P<0.05) than that from Industry B. The mean values of the INVDMD, INVOMD and ME contents of the samples of BYB collected from Industry A were markedly higher (*P*<0.05) than those from Industry B.

Table 6. *Lsmeans for the nutritive values (% DM) and ME (MJ/kg DM) contents of the brewery byproducts and common concentrates.*

Parameter	WSGB		Conc[10]	SEM[9]	P-Value	BYB		SEM	P-value
	Industry A	Industry B				Industry A	Industry B		
No samples (n)	18	21	25			4	12		
DM[1]	26.13^{c}	33.63^{b}	85.68^{a}	0.645	<0.0001	89.26^{a}	12.15^{b}	1.17	<0.0001
CP[2]	24.28^{a}	21.63^{b}	12.46^{c}	0.443	<0.0001	38.81^{b}	53.49^{a}	0.57	<0.0001
NDF[3]	53.03^{a}	50.20^{b}	28.75^{c}	0.638	<0.0001	NA[8]	NA		
ADF[4]	30.43^{a}	24.56^{b}	15.55^{c}	0.6	<0.0001	NA	NA		
INVDMD[5]	65.10^{b}	63.55^{b}	81.46^{a}	2.428	<0.0001	50.65^{a}	14.55^{b}	0.907	<0.0001
INVOMD[6]	61.49^{b}	59.93^{b}	80.40^{a}	3.098	<0.0001	55.85^{a}	38.84^{b}	0.46	<0.0001
ME[7] (MJkg DM)	9.22^{b}	8.99^{b}	12.06^{a}	0.472	<0.0001	8.46^{a}	5.78^{b}	0.168	<0.0001

[1] dry matter, [2]-crude protein, [3]-neutral detergent fibre, [4]-acid detergent fibre, [5] in vitro dry matter digestibility, [6]in vitro organic matter digestibility, [7]Metabolizable Energy [8]Not analysed, [9]Standard error of the mean, [10] common concentrates, [a,b] Mean values with different superscripts within the row differ significantly (P≤0.05)

3.7. Challenges Encountered During the Usage of Brewery Byproducts

The percentage frequencies of the challenges encountered by the respondents in Arusha City and Hai district when using brewery byproducts are presented in Figure 2. A higher percentage of the respondents in the Hai district (58.82%) than those in Arusha City (35.29%) reported insufficient supply of brewery byproducts as a major challenge in using brewery byproducts as animal feed. Large capital for installation of storage structure and bulky (large volume) purchase of the brewery byproducts were other challenges reported by a greater number of respondents in Arusha City (20.59%) than in Hai district (14.71%). However, a higher percentage of the respondents in the Hai district (8.82%) than those in Arusha City (2.94%) reported limited storage facilities as the main challenge on the use of brewery waste. Problem of transportation presented a lesser challenge in Hai district as reported by only 5.88% of the respondents, with a slightly higher percentage in Arusha City (8.82%). On the other hand, frequent changes in the price of brewery byproducts to farmers was reported as a challenge in Arusha City (29.41%) and few (11.76%) respondents in Hai district.

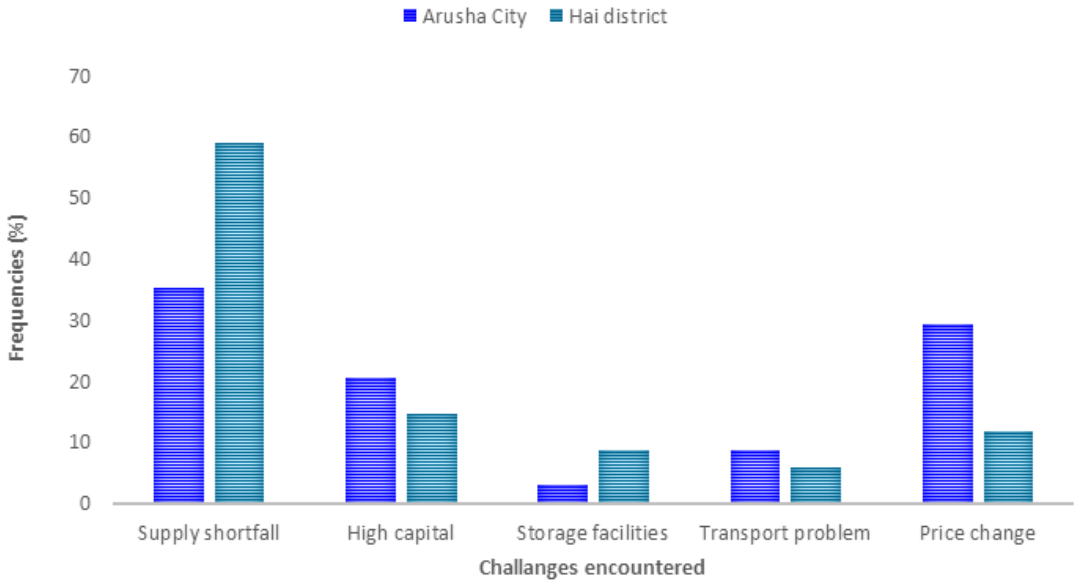

Figure 2. *Percentage frequencies of the major challenges encountered in the usage of brewery byproducts as feed to dairy cattle.*

3.8. Performance of Dairy Cattle Supplemented with Brewery Byproducts

Table 7 presents the effects of supplementing brewery byproducts relative to common concentrate on the performance of dairy cows. Lactating dairy cows fed on brewery byproducts had higher (P<0.05) body weight and milk yield than those supplemented with common concentrate. However, there was no significant (P>0.05) influence of brewery byproduct supplementation observed on the milk quality attributes.

Table 7. *Lsmeans ±SEM of the effects of supplementing brewery byproducts and common concentrates on the performance of the selected dairy cows.*

Parameters	Brewery byproduct	Common concentrate	SEM	P-value
No. of observations	45	31		
Body weight (kg)	363.54[a]	341.63[b]	7.521	0.046
Milk yield (liters/d)	11.69[a]	9.42[b]	0.455	0.005
Milk quality (%)				
Fat	1.616	1.59	0.241	0.942

Parameters	Brewery byproduct	Common concentrate	SEM	P-value
Protein	2.879	2.943	0.262	0.866
Lactose	4.182	4.578	0.222	0.224
Solids	9.573	9.407	0.424	0.786
Solid not fat	7.425	7.888	0.408	0.436

4. Discussion

The study aimed to explore the status and factors affecting the utilization of brewery byproducts as feed sources for dairy cattle. It generally focused on the socioeconomic aspects towards the use of brewery byproducts, evaluating their availability, nutritional values and associated challenges. Additionally, the research examined the effects of brewery byproducts on productive parameters, including body weight, milk yield, and quality attributes of the milk from cows.

The observed tendency that farmers with formal education having a higher likelihood (OR = 5.194) of using brewery byproducts as dairy supplements, implies that education plays a significant role in understanding extension messages and quickly interpreting agricultural technologies through reading books and online resources. Similarly, [34] found that farmers with a formal level of education were more likely to adopt new technologies in agriculture, leading to the increased use of inputs, such as improved seeds and access to credit facilities, resulting in higher outputs. The observed smaller sizes of land for dairy farming owned in Arusha City as compared to the Hai district could be attributed to urbanization, which led to land scarcity in cities, forcing farmers to limit livestock space. Dairy farming in small areas results in inadequate space for grazing and establishing improved forage for cows, increasing production costs due to outsourcing feed materials to optimize animal productivity. Thus, farmers with one acre of land in the study area had a greater (OR=3.241) demand for outsourcing feed materials, such as brewery byproducts than those with some land for grazing and established pastures. Similar results were reported by [29, 36, 37] in Bahir Dar Zuria and Mecha Woreda in Ethiopia, where brewery waste was demanded by smallholder dairy farmers with less space of land for dairying. The observed greater likelihood (OR=3.517) of farmers with more experience (11 to 20 years) in dairying using brewery byproducts than those with less experience suggests the use of skills and knowledge integration particularly in feeding dairy cows among farmers with several years in dairying. However, access to brewery byproducts for new farmers (1 to 10 years in dairy farming) might also be challenging, since the priority of brewery byproducts is primarily available to customers with larger orders and who have established relationships within the brewery industry. The results align with those reported in [33, 35] that experienced farmers had better adoption of new technology to improve farm recording and productivity of dairy cows in their herds. Additionally, higher demand for alternative and cost-effective feed sources among farmers with larger herd sizes was evident in the usage of brewery byproducts (OR=2.946) in the study area. These results are consistent with the observations made by [14], which demonstrated that big herd size of cattle encourages farmers to select the most cost-effective and high-quality inputs to maximize profit. The increased number of farmers practicing mixed farming in Hai district could be attributed to the availability of land for both grazing and crop farming activities. The study by [30] similarly observed that most dairy cattle farmers in rural areas typically possess large plots of land for grazing and pasture establishment. The greater number of heifers seen in Hai district compared with Arusha city could be that farmers prioritize keeping young herds to secure future productive cows. This approach simplifies management by concentrating on animals with proven reproductive and productive traits. According to [31], raising dairy cows from calves to heifers serves as a safeguard for sustaining future milk production and herd quality. The scarcity of land for grazing bulls, coupled with the availability of extension services including affordable artificial insemination in Arusha City, could explain why farmers are not keeping bulls. The result is in agreement with the observation made in Sheikh and Yebu towns in the Jimma zone of Ethiopia [32], where artificial insemination services dominated the breeding practices. In contrast, rural farmers, such as those in Hai district, could be influenced by the availability of large grazing spaces and cultural traditions that encourage them to keep bulls.

The quantities of brewery byproducts produced by the beer factories observed in the present study exceeded those of the two industries in Dashen, Debre Birhan, and Gonder regions in Ethiopia, where each industry produced 4434.9 tons of dry matter of brewery byproducts annually [5]. The demand for beer in a specific area determines the amount of brewery byproduct produced. It has been reported elsewhere [4] that the brew production increased the volume of associated byproducts used in energy production and feeds for livestock. The observed usage of yeast byproducts (LBYB) more in Hai district than in Arusha City was attributed to their availability, since LBYB was produced in higher amounts in Industry B, which is closer to Hai district than in industry A. The dry

brewery yeast byproduct (DBYB) from Industry A was produced in small volumes and supplied to only small number of users.

The observed higher milk yield from cows supplemented with brewery byproducts compared to those supplemented with common concentrates could be due to the higher mean values of CP content showed by WSGB and BYB compared to the common concentrates. The result accords with those of [38, 41, 42, 47, 48], which reported that higher CP content in brewery waste supplies sufficient digestible essential amino acids required for the synthesis of milk in lactating dairy cows. Furthermore, the observed higher mean values of NDF content of WSGB compared to that of common concentrates supplemented to the cows could be the reason for the observed greater body weight and milk yield from those cows compared to their counterparts. This is attributed to the higher energy content from fermentable structural carbohydrates in WSGB relative to those in common concentrates, during their fermentation in the rumen. Additionally, alcoholic materials such as BYB have the advantage of feeding the rumen microbes as a result of increasing their activity during the digesting of structural carbohydrates than those supplemented with the common concentrates [13, 45]. The considerable variation in nutritive levels of WSGB and BYB between locations could be caused by the differences in the types of ingredients used for beer making that determine nutrient diversity as cereals and additives vary in protein and fibre contents. Similarly, [43, 39, 40] explained that different requirements of raw materials for brewing determine the quality of brewery byproducts produced. The nutritional variation observed between dry and liquid brewery yeast byproducts could be attributed to the fact that the dry brewery yeast byproduct, produced from Industry A, is typically recycled based on the recipe requirements within the plant. This is followed by heat treatment using a pulse extraction dryer for the denaturation and deactivation of enzymes and microorganisms in the slurry before it is disposed of as a byproduct [44]. The action leads to increased shelf life of the materials with degradation of some nutrients, such as vitamins and protein, sensitive to high temperature. In Industry B, the yeast is used only once, hence increasing the availability of nutrients in the leftover materials.

The observed insufficient supply of brewery byproducts reported by respondents from the Hai district could stem from the long distance, approximately 30 km, from the brewing industry to the district. This observation aligns with the findings of other workers [16], which indicated that the use of brewery byproducts was higher in dairy farms located near the production site than in those situated further away, due to easier transportation and accessibility of resources. The influences of greater capital requirement associated with constructing storage facilities for brewery waste, bulk purchasing of byproducts, and problems of transportation of materials from the industry to the farms have also been noted in other studies [45, 46]. Price fluctuations reported by the majority of respondents in Arusha City could result from higher demand for the byproducts linked to lower purchasing costs and their potential benefits for dairy cows compared to other commonly used supplements. Furthermore, the operation of brewing industries throughout the year in the zone guarantees the availability of brewery byproducts as feed materials to dairy cows all the time in northern Tanzania.

5. Conclusions and Recommendations

In conclusion, brewery byproducts are potential supplementary feed resources for enhancing sustainable milk production from the dairy cows under a smallholder production system in Northern Tanzania. However, some socioeconomic factors, farm characteristics and insufficient supply of brewery byproducts are limiting the overall effectiveness of using the byproducts. The study recommends further investigations into the cost-benefit analysis of utilizing brewery byproducts as a supplement for lactating dairy cows in smallholder dairy farming.

Abbreviations

WSGB	Wet Spent Grain Byproduct
INVDMD	In Vitro Dry Matter Digestibility
INVOMD	Invitro Organic Matter Digestibility
NIRS	Near Infrared Spectroscopy
NDF	Neutral Detergent Fibre
ADF	Acid Detergent Fibre
CP	Crude Protein
BYB	Brewery Yeast Byproduct
LBYB	Liquid Brewery Yeast Byproduct
DBYB	Dry Brewery Yeast Byproduct
DM	Dry Matter
AOAC	Association of Official Analytical Chemists
ME	Metabolizable Energy
MJ	Megajoules
Kg	Kilogram
HG	Heart Girth
LW	Live Weight
CI	Confidence Interval
OR	Odd Ratio
SUA	Sokoine University of Agriculture
TVLA	Veterinary Laboratory Agency
SPSS	Statistical Package for Social Science
SAS	Statistical Analyses Software
SEM	Standard Error of the Mean
CONC	Common Concentrates

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Conflicts of Interest

The authors declare no conflicts of interest.

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