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Dairy Farming Conditions and Utilization Levels of Liquid Brewers' Yeast in Kenya

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Abstract

Dairy production plays an integral part in supporting smallholder farmers' livelihoods. The desire to increase the number of dairy cattle is not feasible due to the reduced output of feed resources occasioned by climate change. Consequently, the need to increase productivity per cow is inevitable. Conventional protein supplements are costly; hence, the need to explore affordable nutrient-dense alternative feed resources. Liquid brewers' yeast (LBY), a by-product of the brewing industry, is a rich protein supplement in dairy production. This study aimed to assess the dairy farming conditions and utilization levels of LBY as a feed supplement in Githunguri Sub-county, Kiambu. Semi-structured questionnaires were administered to 457 dairy farmers in a cross-sectional survey. The findings revealed that most farmers (94.2%) fed their cattle on established forage/fodder and crop residues with supplementation. Even though 53.1% of the respondents were aware of the use of LBY, only 30.6% utilized it to supplement dairy cows, most of whom (96.0%) used it fresh without preservation. Membership in farmers' organizations increased awareness of LBY ($r = 0.732$). Principal component analysis indicated that the benefits of using LBY outweigh the challenges involved with a loading matrix of 0.891 - 0.954 and 0.681 - 0.807, respectively. The low adoption and use levels of LBY as a source of protein supplements were due to low awareness. There is a need for concerted efforts by stakeholders in the industry to increase farmers' knowledge base on the utilization and effectiveness of LBY in dairy production.

Keywords

Dairy-Production, Liquid Brewers' Yeast, Protein, Supplement

1. Introduction

Agriculture is one of the main socio-economic pillars in many developing countries, contributing to food and nutrition security, per capita income, gross domestic product (GDP) and foreign exchange [1] [2] [3]. Kenya has one of the largest dairy sectors in sub-Saharan Africa, contributing 10% of the country's GDP. The livestock sector contributes 12% to the GDP and 42% of the agricultural GDP [4] [5]. Kenya produces an estimated 4 to 5 billion litres of milk annually from a herd of about 4 million dairy cows, whereby smallholder dairy farms account for 80% of the national milk production [5]. The annual per capita milk consumption is 145 L. At least 800,000 smallholder farmers in Kenya depend on dairy farming for their livelihood, to improve household nutrition, to provide extra income and generate jobs [5]. The growing demand for dairy products is due to population growth, urbanization, rising disposable income levels, and changing lifestyles [6].

The lack of a high-quality, readily available, affordable diet to feed livestock remains the most urgent challenge for smallholder dairy farmers in developing countries [7]. A study by Chollom *et al.* [8] pointed out that livestock production plays an important socio-economic role that has the potential to improve not only income but also the quality of life among the populace in the developing world. Protein feed resources for animal feed formulation are the most expensive ingredients and therefore pose a barrier to livestock production [9]. Improving the availability of quality feeds for the dairy subsector, specifically by enhancing forages, is an intervention that will not only improve individual animal productivity but also has a great potential to reduce greenhouse gas emissions intensities [4].

Dairy farming in Kenya has concentrated in the high-altitude agroecological zones of the central highlands and Rift Valley regions. The areas have high bimodal rainfall and relatively low temperatures of 15˚C - 24˚C [4]. The continual dependence on conventional sources of feed ingredients may not be the solution to the challenges facing the livestock sector in Kenya. Production of feed ingredients from crops such as grains and legumes by local farmers remains inadequate for human and animal nutrition. The alternative is to utilize unconventional supplements such as LBY, which do not directly impact human nutrition [8]. One solution would be to use a relatively high amount of commercial concentrates. However, such concentrates are expensive, hence the need for cheap alternative by-products and waste products obtained from local food processing factories located within farmers' vicinity [7].

Liquid brewers' yeast is the second most abundant by-product from the brewery and distillery industries. It also has rich nutritional composition, making it a valuable feed for cattle [10]. The by-product is usually discarded into the environment as a waste product, causing water bodies pollution and increasing the biological oxygen demand (BOD). Liquid brewer's yeast is a cheap source of protein obtained in areas where breweries are situated [8]. The production of LBY in Kenya is at 20,000 L per day, but only 10% undergo drying due to the high costs involved, and the rest is sold in liquid form. The LBY supply chain originates from producers to distributors and farmers [9]. Despite its benefits, limited information is available on the extent of its utilization as an alternative protein source by farmers. The objective of this study was to assess the dairy farming conditions and utilization levels of LBY as a feed supplement for dairy production in Githunguri.

2. Methodology

2.1. Study Area

The study was conducted in Githunguri sub-county within Kiambu County, Kenya. The area is 1600 m above sea level and lies between latitude 1˚05" and 1˚06" South of the Equator and longitude 36˚53" and 36˚55". The soils are deep, well-drained dark reddish to brown, friable clay, with a bimodal rainfall regime that starts in mid-March with a peak in April-May while the second begins in mid to end of October with an annual average of about 1065 mm. The mean maximum monthly temperature in the region varies from 22.4˚C to 27.6˚C, while the mean minimum temperature ranges from 11.3˚C to 14.9˚C [9]. Kiambu County has four distinct topographical zones. Upper Highland, Lower Highland, Upper Midland, and Lower Midland Zones. Githunguri is 1500 - 1800 metres above sea level in the lower highland zone. The area is a tea and dairy zone characterized by hills, plateaus and high-elevation plains. The sub-county has high-level upland fertile soils from volcanic rocks, making it suitable for agriculture, including dairy farming [11].

2.2. Study Design and Data Collection Procedures

Data was collected using a semi-structured questionnaire, and 457 respondents were interviewed. The questionnaire captured data on the dairy farmers' practice on forage/fodder management, general feeding of the animals, utilization of LBY vis-a-vis other supplements, and associated benefits and challenges. The questionnaire was pre-tested to assess its validity.

Sample size and selection of respondent

The sample size was determined using a formula by Cochran [12] in Equation (1):

$$n = \frac{Z^2 pq}{e^2} \tag{1}$$

where:

n = sample size;

Z^2 = abscissa of a normal curve which is 1.96 for a 95 confidence interval;

p = estimated proportion of an attribute;

$q = (1 - p)$;

e = desired level of precision set at 0.05.

The formula required a minimum of 385 respondents for the study. A further 5% precision and 10% to cater for non-response were factored in. This increased the sample size to 443 households. To increase the external validity of the study outcome, the sample size was increased proportionately across the wards leading to 457 homes. The study households used multistage sampling to capture all the desired information. To increase the data's validity and obtain a representative sample [13], some households that utilize LBY as a supplement in dairy production were purposively sampled. The questionnaire was tested for reliability using Cronbach's coefficient alpha (α) [14]. This study set a standard for the reliability correlation coefficient to be 0.7 and higher. A reliability correlation coefficient above 0.7 shows a high internal consistency.

2.3. Data Analysis

Data collected from the cross-sectional survey was analyzed using SPSS statistics software version 26 at a 95% confidence level. Both descriptive and inferential statistics were used to analyze data. Descriptive statistics were used on the practices of farmers on fodder/forage, feeding and supplementation. In contrast, inferential statistics with a chi-square test were applied to differentiate reasons for preferring the type of breed kept by the farmer. Principal Component analysis (PCA) was used to cluster benefits and challenges associated with using LBY in the order of priority. Linear regression models were used to identify the determinants of farmers' awareness of LBY as a feed supplement. Non-significant terms were eliminated from the model. The regression model used is as indicated in Equation (2):

$$y_i = \beta_0 + \beta_i x_i + \cdots + \beta_n x_n + \epsilon_i \quad (2)$$

where y_i is the farm-level indicator for farmers' i awareness of LBY, β_o is the intercept, β_i, …, β_n are coefficients to be estimated and x_i, …, x_n is a vector of farm practices, ϵ_i is the error term.

3. Results

3.1. General Characteristics of Githunguri Dairy Farmers

Most respondents (85.1%) were either the household head or the household head's spouse (**Figure 1**). The other respondents include farm managers (7.2%), sons at (4.1%) and daughters (3.6%). Furthermore, the majority (79.6%) of the respondents were aged 35 years and above, while 20.4% were below this age. Moreover, 98.9% of the respondents had formal education. The study further revealed that 91.9% of the respondents were members of farmer's organizations. Years of experience in dairy farming ranged from less than five years (28.4%) to more than twenty years (19.2%), as indicated in **Figure 1**.

The average dairy herd on the farms was six cows, four of which were in lactation, two dry cows and two heifers. It takes 6.18 ± 2.88 years before the disposal of cows from the herd (**Table 1**).

3.2. Pasture and Fodder Production Practices

The results indicate that most respondents planted forage/fodder (94.2%), and

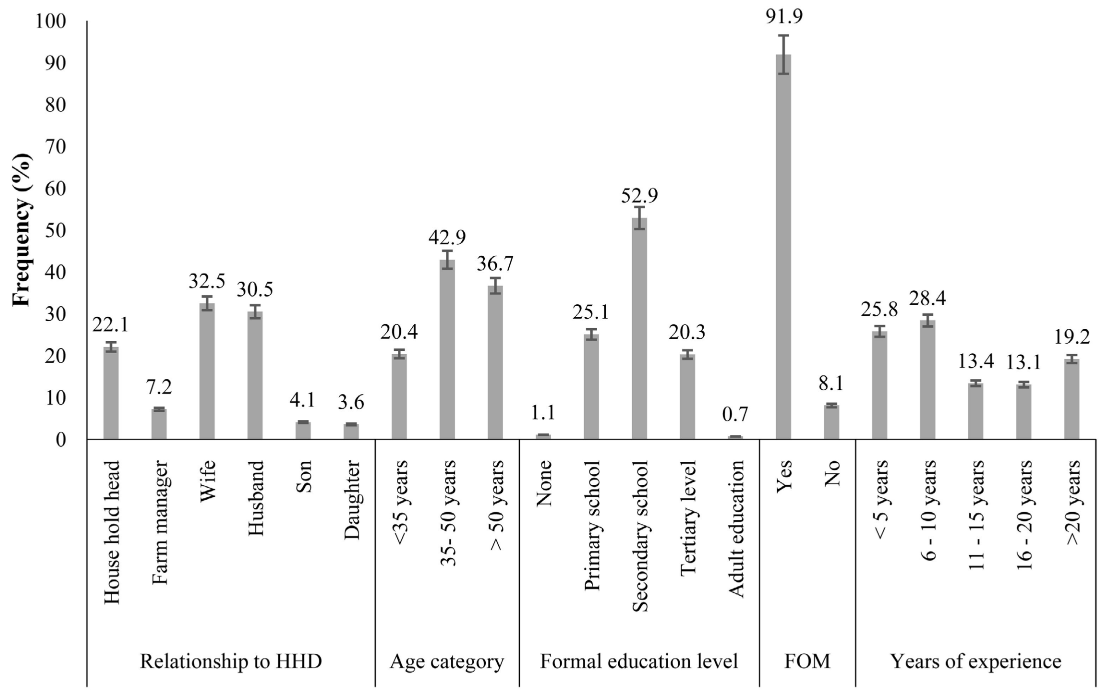

Figure 1. General characteristics of the Githunguri dairy farmers (HHD = Household head; FOM = Farmers' Organization Membership.

Table 1. Dairy herd structure and longevity in Githunguri.

Parameter	Mean	Min.	Max.	Std.
Total herd (No.)	6	1	57.0	7.33
Milking cows (No.)	4	0	32.0	3.88
Dry cows (No.)	2	0	16.0	1.72
Heifers (No.)	2	0	15.0	1.92
Longevity (Yrs.)	6.18	1	15.0	2.88

Key: No. = Number, Yrs. = Years, Min. = Minimum; Max. = Maximum; Std. = Standard deviation.

46.9% used fertilizers. Many farmers (94.1%) feed their cattle on crop residues, and 18.8% feed cattle on industrial fruit waste. A more significant percentage (28.5%) of the farmers who did not use fertilizers claimed that their land was fertile, and (22.8%) attributed it to the high cost of fertilizers. Similarly, most of the farmers (94.1%) fed their dairy cattle on crop residues and 18.8% used industrial fruit waste, as shown in (Figure 2).

Common pastures and fodder crops grown by dairy farmers are shown in Table 2. Napier grass (*Pennisetum purpureum*) and Maize (*Zea mays*) were the most planted fodder crops by 92.1% and 52.5% of the respondents, with an average acreage of 1.36 and 0.77, respectively. The mainly cultivated legumes were Leucaena (*Leucaena Leucocephala*) and Desmodium (*Desmodium spp.*), with a moderate parcel of 0.90 and 0.70 acres, respectively (Table 2).

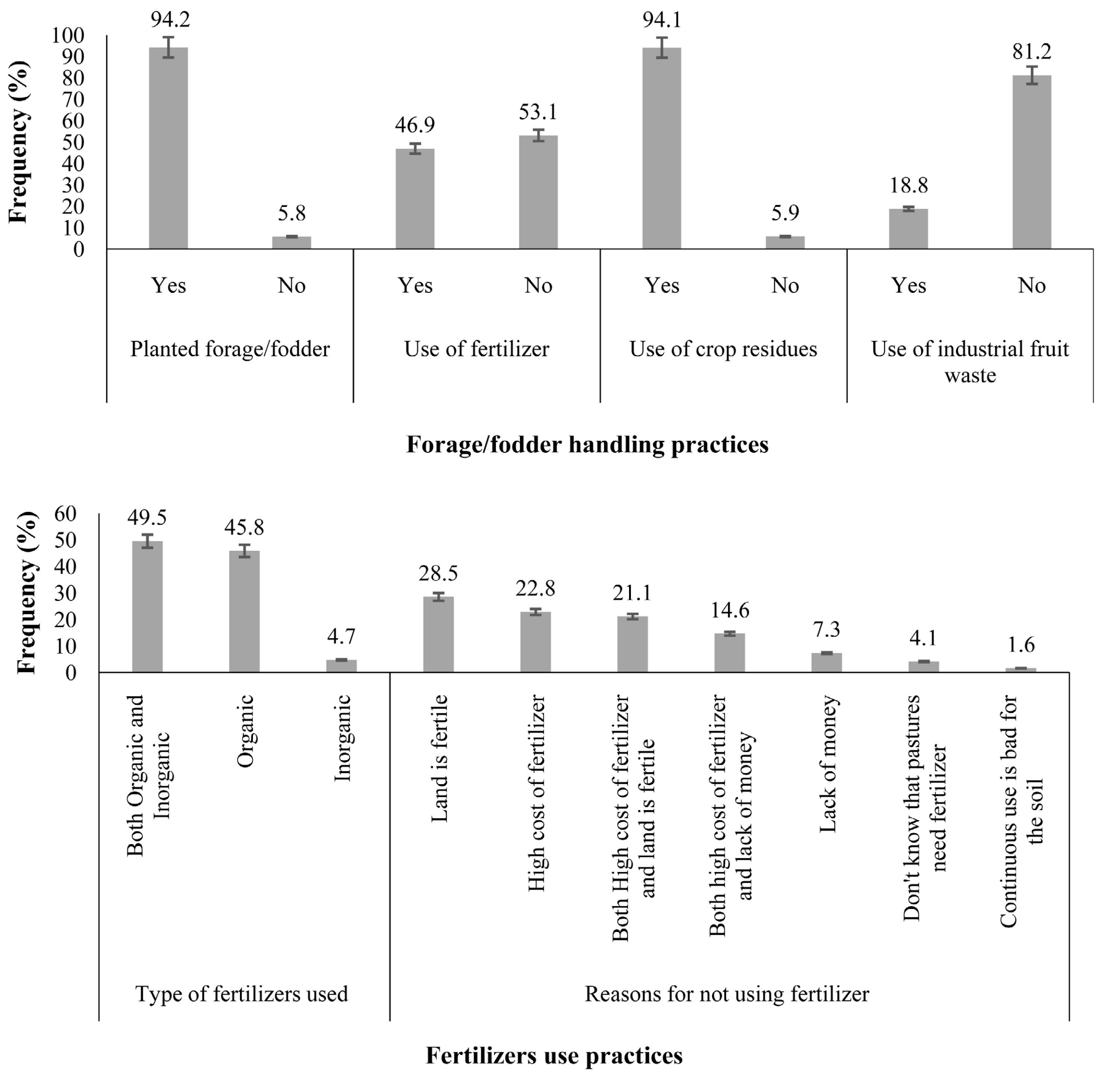

Figure 2. Githunguri dairy farmers' forage and fodder handling and management practices.

Table 2. Common pasture and fodder crops established in Githunguri.

	Frequency (%)	Acreage				Production level		
		Mean	Min.	Max.	Std.	Mean	Min.	Max.
Napier grass(*Pennisetum purperium*)	92.12	1.36	0.10	19.51	1.61	4.50	1.00	5.00
Kikuyu grass (*Pennisetum clandestinum*)	26	0.59	0.01	1.00	0.31	3.71	3.00	4.00
Signal grass (*Brachiaria spp.*)	6	0.75	0.01	1.00	0.42	2.29	1.00	4.00
Maize (*Zea mays*)	52.50	0.77	0.01	5.00	0.59	3.69	1.00	5.00
Desmodium (*Desmodium spp.*)	10	0.70	0.50	1.00	0.26	2.83	1.00	4.00
Leucaena (*Leucaena leucocephala*)	1	0.90	0.90	0.90	0.00	2.00	2.00	2.00
Calliandra (*Caliandra spp.*)	4	0.33	0.01	0.50	0.21	3.00	3.00	3.00

Key: Min. = Minimum; Max. = Maximum; Std. = Standard deviation. Production level ranking, 1 = poor, 2 = fair, 3 = moderate, 4 = high, 5 = Very high.

The conservation of forage/fodder and dairy cattle feeding strategies in Githunguri are in Table 3. Stall feeding was the most commonly practiced system (98.2%). Although most farmers (37.9%) do not practice feed conservation, 30.0% conserve feed as hay, 9.8% silage and 22.3% as Silage and hay. The most preferred crop residue for feeding dairy cattle was maize residues (64.4%), followed by both maize and wheat residues 21% (Table 3).

Most farmers (65.1%) do not use total mixed rations (Figure 3). However, 98.7% provide concentrate to lactating cows. Most farmers who used dairy feed supplements (97.5%) provided it to animals during morning and evening milking. Also, 87.4% of the farmers practiced steaming up before calving.

Table 3. Conservation of forage/fodder and feeding strategies by Githunguri dairy farmers.

Practice	Levels	Frequency (%)
Type of feeding system	Stall feeding (Zero grazing)	98.2
	Stall feeding and grazing	1.1
	Grazing	0.7
Method of conserving feed	None	37.9
	Hay	30.0
	Both Silage and hay	22.3
	Silage	9..8
Types of crop residues used	Maize residues only	64.4
	Both maize and wheat residues	21.1
	Maize, beans and rice residues	3.8
	Both maize and rice residues	2.3
	Both maize and beans residues	1.8
	Maize, beans and wheat residues	1.8
	Maize, beans, rice and barley residues	1.3
	Others	3.9

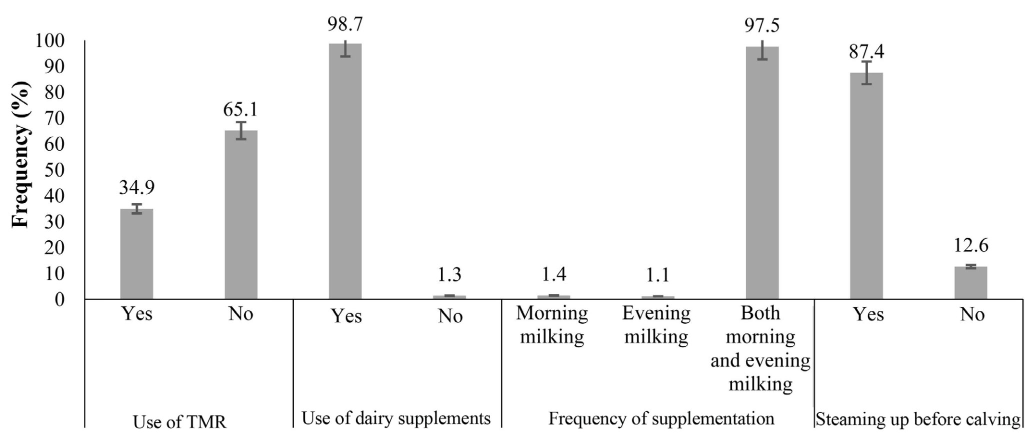

Figure 3. Dairy cattle feeding practices in Githunguri.

Results indicate that only a small proportion (13.8%) of the respondents do not estimate the amount of fodder fed to cattle, but the majority estimated using feed troughs (37.2%) and gunny bags (36.0%). Most farmers (87.0%) used only concentrates to supplement their cattle, mainly to increase milk production (35.7%) as indicated in **Table 4**.

Table 4. Forage estimation methods and feed supplement management practices.

Practice	Level	Frequency (%)
How to estimate the amount of forage	Do not estimate	13.8
	Feed troughs	37.2
	Gunny bags	36.0
	Weighing scale	4.3
	Both feed trough and gunny bags	6.2
	Both feed trough and weighing scale	1.9
	Gunny bag, weighing scale or feed trough	0.4
Type of supplement used	Concentrate	87.0
	Forage	0.5
	Both concentrate and forage	12.5
Factors considered for supplementation	Milk production only	35.7
	Supplement affordability only	2.9
	Availability of feed supplement only	7.9
	Both milk production and supplement affordability	7.0
	Both milk production and the availability of feed supplements	24.7
	Both affordability and availability of feed supplements	0.7
	Milk production, availability and affordability of feed supplements	20.9
	Balanced diet	0.2
Strategy for supplementing	Uniform rate	27.6
	Based on milk production	67.1
	Both milk production and the body of the cow	0.4
	Both milk production and cost	4.9

3.3. Liquid Brewers' Yeast Utilization

The adoption and handling practices of spent liquid brewers' yeast by Githunguri farmers are in **Figure 4**. Whereas 53.1% of the farmers know LBY as an animal feed, only 30.6% use it. Of the farmers that have adopted LBY use, 96.0% do not preserve it, and only 17.2% received training on handling practices.

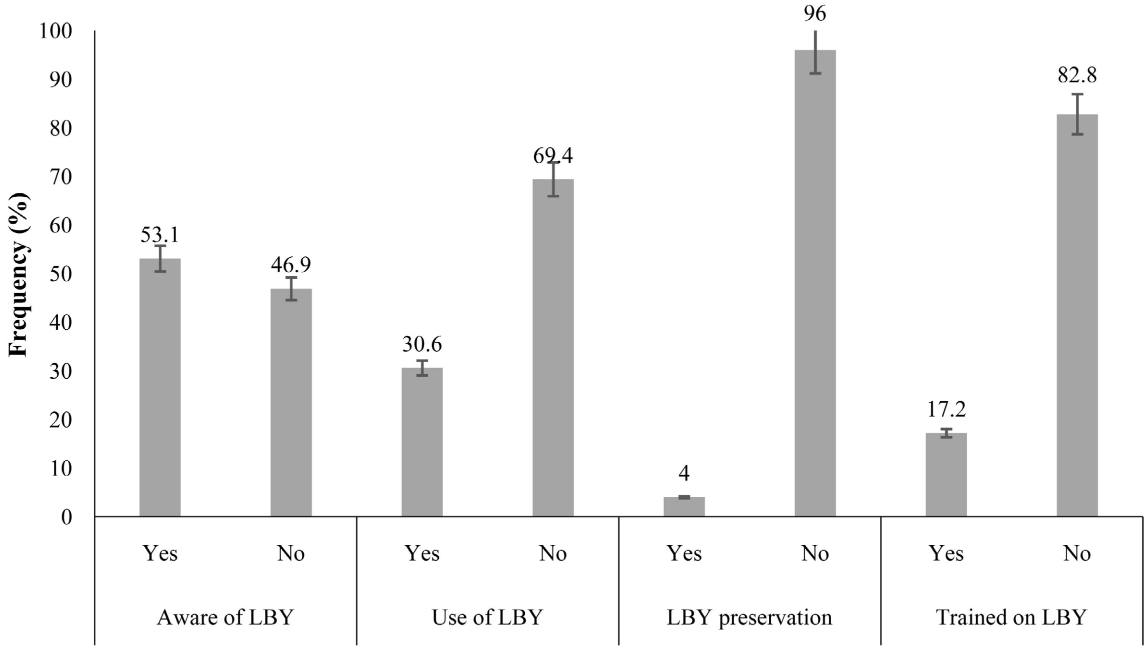

Figure 4. Githunguri dairy farmers' adoption and handling practices of Liquid brewers' yeast.

The regression model of practices that significantly influenced Githunguri farmers' awareness of LBY is in **Table 5**. Findings demonstrated that farmers who feed cattle on industrial fruits by-products and those who apply fertilizers to forages/fodders had significantly less awareness of LBY as a feed supplement at r = −0.071 and r = −0.388, respectively. However, farmers who were members of the organization and those who practiced steaming up to cattle before calving had a significantly higher awareness of LBY use at r = 0.732 and r = 0.344, respectively.

Table 5. Regression analysis of LBY handling practices and adoption.

Model	R	Std. Error	t	Sig.
Intercept	0.963	0.319	3.023	0.004
Do you feed industrial fruits by-products to animals?	−0.071	0.018	−3.958	0.000
Do you steam up your in-calf cows before calving?	0.344	0.124	2.765	0.008
Do you apply fertilizer to your forages?	−0.388	0.114	−3.421	0.001
Membership in farmer organization	0.732	0.228	3.208	0.002

a. Dependent Variable: Are you aware of liquid brewers' yeast?

Liquid brewers' yeast utilization and management by Githunguri dairy farmers are in **Table 6**. Farmers daily use an average of 12.6 litres on milking cows; consumption per heifer is 2.22 L and 1 L per weaned calves. Farmers procure a litre/kg LBY at an average price of KES. 10.6, store it at 22.3˚C and it takes 7.57 days for it to spoil.

Table 6. Utilization and management of liquid brewers' yeast by Githunguri dairy farmers.

Utilization and management practices	Mean	Min.	Max.	Std.
Cost of liquid brewers' yeast (KES./litre or Kg)	10.57	6	30	7.57
Milking cows daily quantities fed	12.64	1	80	21.19
Heifers daily quantities fed	2.22	1	5	1.30
Weaned calves daily quantities fed	1.00	1	1	0.26
The temperature at which LBY is stored	22.25	18	25	2.89
Days to spoilage of LBY	7.57	3	14	3.95

Key: LBY = Liquid Brewers' Yeast; Min. = Minimum; Max. = Maximum; Std. = Standard deviation.

The handling and management practices for LBY are in Table 7. Among the farmers who were aware of the LBY use as an animal feed, 76.7% received the information from other farmers, 2.3% from the media and 21% from several sources that included extension officers, cooperative dairy societies, research institutions, agro-vets and agricultural shows. Of the farmers that use LBY, a majority (81.3%) purchase it from the distributors; 12.5% buy from both distributors and middlemen, whereas 6.3% procure from the middlemen. The majority (92.0%) of the farmers that utilize LBY for cattle feed it in fresh form, while (4.0%) use it after preservation and (4.0%) utilize it in either fresh form or after preservation. Liquid brewers' yeast quality was rated as spoilt by farmers on observation of visible mould growth (15.4%), change in smell (23.1%), change in texture (23.1%) and remaining (38.4%) used a combination of the attributes and decreased uptake by dairy animals.

Table 7. Handling and management practices for liquid brewers' yeast by Githunguri dairy farmers.

Practice	Level	Frequency (%)
Source of information on LBY	Other farmers	76.7
	Media	2.3
	Both extensions officers and other farmers	4.7
	Both extension workers and dairy cooperative	2.3
	Both agricultural shows and other farmers	2.3
	Both research institutions and media	2.3
	All the above channels	4.7
	Both agro-vets and other farmers	2.3
	Both agricultural shows and research institutions	2.3

Continued

LBY source	Distributors	81.3
	Both distributors and middlemen	12.5
	Middlemen	6.3
LBY feeding	Fresh	92.0
	After preservation	4.0
	Both fresh and after preservation	4.0
Quality deterioration	Visible mould growth	15.4
	Change in smell	23.1
	Change in texture	23.1
	Visible mould growth, change in smell, change in texture and decreased uptake by the animal	38.4

Mean scores on preference, benefits and challenges of feeding cattle on LBY compared to other feeds are in Table 8. An average score of LBY preference of 2.83 ± 1.40 was not different compared to the cotton seed cake preference of 3.00 ± 1.14 and preference for sunflower cake of 2.88 ± 1.31. Inexpensive, readily available, improved milk yield, tasty to cattle, better quality and ability to purchase in required quantities were ranked as important benefits of LBY with a mean of between 2.39 - 2.79. In contrast, an improvement in the growth rate of young cattle was categorized as a less important benefit, with an average of 3.14. High transportation costs compared to other protein sources were the major challenge in its utilization as a feed supplement, with an average of 2.82.

Table 8. Ranking of preference, benefits and challenges of feeding cattle on LBY compared to other feed sources.

Factor		Mean	Std.
Preference for feeding dairy animals	Cotton seed cake preference	3.00	1.14
	Sunflower seed cake Preference	2.88	1.31
	LBY preference	2.83	1.40
Benefits of feeding dairy cattle with LBY	Inexpensive as compared to other protein sources	2.39	1.47
	Readily available as compared to other protein sources	2.71	1.38
	Improve milk yields as compared to other protein sources	2.46	1.48
	Improves growth of young dairy stock as compared to other protein sources	3.14	1.21
	Dairy cattle like its taste more than other protein sources	2.79	1.40
	Better quality as compared to other protein sources	2.71	1.33
	A farmer can purchase required quantities at any time	2.71	1.30

Continued

Challenges of feeding dairy cattle on LBY	Short shelf life as compared to other protein sources	3.18	1.25
	Bulky and hence cumbersome to transport as compared to other protein sources	3.00	1.31
	High transportation costs as compared to other protein sources	2.82	1.31
	Not readily available as compared to other protein sources	3.32	1.19
	Cannot purchase required quantities at any time	3.39	0.99
	Do not know appropriate quantities to supplement dairy cattle	3.19	1.08
	Dairy cattle do not like its taste as compared to other protein sources	3.43	1.10

Key: LBY = Liquid Brewers' Yeast; Preference of liquid brewers' yeast over cotton seed cake and sunflower cake: 1 = Most preferred 2 = Preferred 3 = Less preferred 4 = Not preferred. Benefits of feeding dairy cattle with liquid brewers' yeast; 1 = Most important; 2 = Important; 3 = Less important 4 = Not important. Challenges of feeding dairy cattle with liquid brewers' yeast 1 = Most important; 2 = Important; 3 = Less important 4 = Not important.

The loading matrix of benefits and challenges associated with using LBY on principal components is in **Table 9**. It was determined that there were three principal components, where benefits associated with using LBY had a very strong positive loading on principal component 1. Challenges associated with using LBY had a very strong positive loading on principal component 2. Principal component 3 had a slightly strong positive loading of one benefit (improves growth = 0.534) and one challenge (bulky and cumbersome to transport = 0.596).

Table 9. Loading matrix of benefits and challenges of using LBY on principal components.

Category	Factor	Principal Component		
		1	2	3
Benefits	Improves milk yields	0.954	-	-
	Inexpensive	0.940	-	-
	Purchase required quantities at any time	0.940		
	Better quality	0.926	-	-
	Dairy cattle like the taste	0.891	-	
	Improve growth	0.654	-	0.534
Challenges	High transport cost	-	0.807	-
	Dairy cattle do not like the taste	-	0.796	-
	Do not know appropriate feeding quantities	-	0.789	-

Continued

	Cannot purchase required quantities	-	0.777	-
	Not readily available protein	-	0.733	-
	Bulky and cumbersome to transport	-	0.771	0.596
	Short shelf life	-	0.681	-

4. Discussion

4.1. General Characteristics of Githunguri Dairy Farmers

The general characteristics of dairy farmers in Githunguri, as shown in **Figure 1** and **Table 1**, indicate that the majority are above 35 years of age, own six cows, have high literacy levels, and belong to farmer organizations. The findings demonstrated that farmers in the study area have slightly larger average herd sizes. This is contrary to Kashangaki and Ericksen [4], who reported that a smallholder dairy farmer in Kenya typically owns between one and five herds of cattle. Most of the farmers have experience of more than five years in dairy farming. According to Svensson *et al.* [15], a dairy farmer's experience is essential in implementing farm management practices, especially herd health management, for enhanced profitability. The level of education, herd size, and access to credit facilities determine the adoption of improved technologies [16] [17]. The high literacy level and more years of experience by farmers in the area have enabled them to develop innovative management strategies that have significantly improved dairy production.

The study area demonstrated a unique style of leadership where gender had no impact on the heading of households because both genders were heads in almost equal proportions. A similar observation on dairy farmers in Githunguri by Aguda [11] reported that they are predominantly male and female small-scale farmers who depend on rain-fed agriculture for production. Women's involvement in raising livestock is a long-standing African tradition [18]. The findings correlate with East and Central African studies that suggest that women are the caretakers in farming systems where stall-feeding is practiced. The revenue generated from the sale of milk enables women to improve their status at both household and community levels [19]. Changes in the economic and socio-political conditions have led to increased participation of women in this industry. However, their contributions continue to be unnoticed, and the database of their involvement remains limited [18]. Thus, a challenge in knowing where inputs to help women increase their productivity or reduce their labour bottlenecks can be directed.

4.2. Pasture, Fodder and Feed Management

Figure 2 and **Table 2** indicate that farmers in the area had established forage on their farms, including Napier grass, Kikuyu grass, and maize. The most prevalent fodder was Napier grass (92.1%), implying that dairy farmers in the study area heavily rely on it. As much as 46% of the farmers use organic fertilizers to grow fodder/forage, more than 50% do not use fertilizer on their farms, citing good soil fertility. Such farmers should be enlightened on the importance of organic manure; that is plenty in the area due to stall-feeding, and disposal is a significant challenge. Most farmers dump it on the roadside. The microbial processes and chemical reactions on heaps of manure along the roadside may lead to a release of methane (CH_4), nitrous oxide (N_2O), ammonia (NH_3) and carbon dioxide (CO_2) [20] [21].

Pasture and fodder production in the study area is mainly rain-fed, and most farmers conserve the surplus either as hay or Silage. The main challenge of this practice is that production systems rely on rain in wet seasons. As a result, most farmers face regular feed shortages during the dry season [4] [21] [22]. Dairy cattle feeding trends varied in the area, with most farmers using feed troughs followed by gunny bags to estimate feeds. The recommended practice is that the amount of feed for dairy cattle should be based on body weight and productivity. However, weighing feed is not a common practice in the study area (**Table 4**). Failure to follow accurate feeding management can adversely affect the production potentials of dairy cattle as milk production directly correlate to feeding trends. These findings concur with a study by Alaru [9].

Crop residues constitute a greater feed resource besides forage or fodder, as shown in **Figure 2**. The most used crop residue is maize stovers, as in **Table 2**. A study by Kolk [22] reported similar results. It attributed this to the availability and the low cost of crop residues, especially maize stovers for those who practice zero-grazing during the dry season. However, the primary constraint to the availability of crop residues is the limited land for cultivation, which means some producers face year-round feed shortages [4]. Most farmers in the study area own less than one acre of land and thus cannot get enough crop residues from their farms, forcing them to buy from other sources. Besides crop residues, one in every five farmers uses industrial fruit waste and all reported the use of pineapple pulp. The findings are in tandem with the study of Kamphayae *et al.* [7]. The proximity of the area to pineapple plantations and processing plant make it easier for the farmers to access the pulp at a lower price, thereby lowering the cost of production.

Almost all farmers use supplements during morning and evening milking (**Figure 3** and **Table 4**). Whereas a substantial proportion of farmers relied on milk production as the primary basis for providing supplements, the availability and affordability of the feed supplements played a significant role in their decision. The use of total mixed rations was widespread in the area, indicating a rich knowledge base on dairy feeds and feeding by the farmers. Conversely, farmers undertook steaming up to in-calf dairy cows. Milk yield per day, total milk yield, lactation length and birth weight of calves are higher in farms that practice steaming up to dairy cattle [23].

4.3. Utilization of Liquid Brewers' Yeast

It is interesting to note that more than 53% of the respondents are aware of the use of LBY as a feed supplement. However, only 31% of those who were aware were using it at the time of the study (**Figure 4**). Membership in a farmers' organization and the practice of steaming up cows before calving positively influenced the adoption of LBY as a feed supplement (**Table 5**). This observation can be due to information-sharing strategies available at farmers' organizations such as the Githunguri Dairy Farmers' Cooperative Society (GDFCS). Members of farmers' cooperative societies gain more benefits through knowledge sharing on market stability, services, and opportunities for decision-making, social interaction and civic engagement [24]. The ability to generate, disseminate, and share critical information with communities participating in farming activities is the solution to enhanced agricultural productivity [25]. The respondents acknowledged elaborate knowledge-sharing mechanisms employed by the cooperative society to enable information on good farming practices to reach farmers through its more comprehensive extension network. It is important to note that most farmers unaware of LBY utilization are not members of GDFCS.

Farmers use an average of 12.6 L of LBY at the cost of KES 11 per litres. This translates to a daily expenditure of KES 139 on LBY on a farm with an average of six lactating cows (**Table 6**). However, the finding points out (based on the price of LBY per L) that the by-product is a cheaper alternative to the conventional concentrate supplements that are very expensive.

It was observed in **Table 7** that farmers who were aware of LBY as a feed supplement obtained this information mainly from their fellow farmers. Even though farmers shared the idea, the adoption rate was low. Furthermore, a substantial percentage of farmers aware of LBY had not received training on its utilization (**Figure 4**). The study revealed that crucial stakeholders in the dairy sector had not educated farmers *en masse* on the benefits of using LBY in dairy production. Hence, this could be a contributing factor to the low adoption of the use of LBY in the area despite being near brewing industries. The supply chain of LBY is from brewing industries to suppliers, distributors and middlemen or farmers. However, some large-scale farmers can procure the by-product directly from the depot [9].

The primary concern is that it takes only seven days for LBY to spoil, as seen in **Table 6**. The observation agrees with the findings of Alaru [9], that reported a significant increase in microbial load after seven days of purchase. The study recommended that farmers use the by-product within seven days after procurement. **Table 7** and **Figure 4** findings indicate that most farmers feed the by-product when fresh without any form of preservation. During the purchase of LBY from distributors, a farmer needs to gather information on the last replenishment date of the by-product at a distribution point. They would then estimate the feeding duration for the procured LBY before spoilage. The leading indicators used to gauge quality deterioration on LBY are visible mould growth, change in smell, change in texture and decreased uptake of LBY by the animals. Westendorf and Wohlt [26] pointed out that the chief concern about the use of LBY relates to spoilage, which results in a less palatable product that may cause health concerns to animals. The application of cost-effective preservatives may be a viable approach to preventing nutrient losses [10]. However, more precaution is necessary regarding food preservatives to avoid residual effects on animal by-products. Though farmers in this study stored LBY at an average temperature of 22.5˚C, considered a slightly safe storage condition, spoilage was a challenge, as indicated in the ranking of challenges in **Table 9**. The spoilage challenge can be attributed to contamination and multiplication by lactic acid bacteria during storage [9]. In addition, Wang *et al.* [27] showed that spoilage was apparent at higher temperatures, such as 25˚C and 35˚C, causing nutrient content to decrease concomitantly with prolonged storage times and increasing temperatures.

Preference levels for LBY as a protein supplement in dairy farming compared to cotton and sunflower seed cakes were assessed and rated. Farmers who use LBY scored higher than the other two conventional animal protein sources, as shown in **Table 8**. The observation is due to the cost of LBY, which is lower than the two protein sources. The benefits of LBY, as reported by respondents, are improvement in milk yield, reduction in cost, better quality, higher taste preference by dairy cows and availability of the by-product. However, improving the growth rate of young dairy stock was rated as a less critical benefit. The main challenge associated with using LBY is the high transport cost due to its bulkiness.

Nonetheless, it was established that the benefits of its use in dairy production outweigh the limitations based on the experience of the farmers, as illustrated in **Table 9**. Moreover, drying the by-product requires expensive machinery and high energy cost, making it unsustainable unless under a specialty feed formulation arrangement. Ideally, less than 10% of LBY is dried in large brewing industries, and the remaining portion is sold in liquid form [9]. The perishable and bulky nature of LBY calls for developing strategies and techniques to standardize it for long-term storage under tropical conditions; preferably, using solar energy to dehydrate and reduce its bulkiness is inevitable.

5. Conclusion

The study established that most farmers in Githunguri sub-county own an average of six dairy cattle, mainly under stall feeding. Even though more than half of the farmers know LBY as a dairy cattle feed supplement, the adoption rate is low. Hence, the need for concerted efforts by stakeholders in the industry to increase farmers' knowledge base on the utilization and effectiveness of LBY as an affordable alternative protein source for sustainable and economically viable dairy production.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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