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Physicochemical and microbiological evaluation of yoghurt sold in Addis Ababa, Ethiopia

Takele Wolkaro[1*], Mihret Frew[2] and Ulfina Galmessa[3]

Abstract

Background Increase in demand for yoghurt in Addis Ababa, in recent times has led to proliferation of different kinds of commercially produced (branded) yoghurt in line with the traditional (unbranded) one in the market. However, limited or no available data for the quality of gradually increasing different kinds of commercially produced (branded) yoghurt in line with the traditional (unbranded) one in the market. It was therefore vital to evaluate the physicochemical property and microbial quality of yoghurt sold in Addis Ababa in order to determine its quality and perhaps safeguard the health and wellbeing of the numerous people consuming yoghurt products.

Methods A total of 40 yoghurt samples consisted of 20 traditionally (unbranded) and 20 commercially produced (branded) were analysis for physicochemical property (pH, moisture, ash, fat, Total Solid (TS) and Solid Not Fat (SNF)) and microbial quality (Coliform Count (CC) and Yeast and Mould Count (YMC) were performed using TEMPO system whereas; Total Viable Count (TVC) was performed according to standard culture method).

Results In the traditionally produced (unbranded) yogurt samples, the fat content was 4.44%, pH 3.99, TS content 10.12%, SNF content 7.18%, moisture content 89.88%, and ash content 0.53%. For the commercially produced (branded) yogurt samples, the fat content was 5.02%, pH 3.88, TS content 10.66%, SNF content 8.10%, moisture content 89.29%, and ash content 0.62%. The TVC in traditionally (unbranded) and commercially produced (branded) yoghurt samples was found to be 10.72 and 10.35 $\log_{10}$ cfu/mL, respectively. In terms of coliform counts (CC), 20%, 55%, and 25% of the traditionally produced yogurt samples had counts of <10 cfu/mL, 10 to $<4.9\times10^4$ cfu/mL, and $>4.9\times10^4$ cfu/mL, respectively. For the commercially produced yogurt samples, 40%, 35%, and 25% fell within these same ranges. The overall mean coliform counts were 3.72 $\log_{10}$ cfu/mL for traditionally produced yogurt samples and 2.81 $\log_{10}$ cfu/mL for commercially produced yogurt samples; however, the difference was not statistically significant ($P>0.05$). Similarly, for yeast and mold counts (YMC), 0%, 35%, and 65% of traditionally produced yogurt samples had counts of <100 cfu/mL, 100—$<4.9\times10^4$ cfu/mL, and $>4.9\times10^4$ cfu/mL, respectively. In commercially produced yogurt, 30%, 50%, and 20% of samples fell within these same ranges. The overall mean YMC was 4.48 $\log_{10}$ cfu/mL for traditionally produced yogurt samples and 3.92 $\log_{10}$ cfu/mL for commercially produced yogurt samples, but this difference was also not statistically significant ($P>0.05$).

Conclusion Based on the findings of this study, it is crucial to implement measures to improve the quality of yogurt in Addis Ababa to ensure consumer safety and product consistency.

Keywords Commercially, Quality, Traditionally, Yoghurt

*Correspondence:
Takele Wolkaro
takelewolkaro@yahoo.com
Full list of author information is available at the end of the article

Introduction

Of all fermented dairy products, yogurt is widely accepted for its nutritional and health benefits worldwide [1]. In Ethiopia, significant diversity in yogurt products is anticipated due to rapid population growth, urbanization, evolving consumer preferences, and increasing income levels [2, 3]. According to the Central Statistical Agency (CSA) reports, urbanization rates have risen significantly, resulting in higher consumption of processed foods, including dairy products [4]. This surge in demand for yogurt in Addis Ababa has led to the proliferation of various commercially produced (branded) yogurts alongside traditional (unbranded) varieties in the market [5]. However, yogurt production raises substantial concerns for both the dairy industry and public health authorities.

Ergo is a traditional, spontaneously fermented milk product resembling yogurt, cherished and consumed across all regions of Ethiopia by individuals of all age groups [6]. Ergo can be produced from the milk of various domestic animals, including cows, goats, and camels; however, cow raw milk is predominantly used as the base material for its production [7]. The production of ergo typically occurs through a natural fermentation process without controlled conditions, such as milk standardization, culture concentration, viability, incubation temperature, and time [8]. Therefore, determining the wholesomeness of the physicochemical properties and microbial load of traditionally produced ergo is particularly important, as fermentation is a self-limiting process [9].

In contrast, yogurt produced in commercial dairy plants is manufactured under controlled conditions within processing facilities and is subsequently transported using temperature-controlled trucks [5]. However, most dairy processing plants in Ethiopia source raw milk from smallholder producers, where basic amenities for food safety are often lacking [7]. Consequently, the microbial quality of the milk may directly influence the quality of commercially produced (branded) yogurt. This issue is exacerbated by poorly enforced food laws and regulatory systems [10]. Given the frequent consumption and increasing demand for yogurt, there is a pressing need for continuous assessment of the physicochemical properties and microbiological quality of these products [11].

Reports on foodborne illnesses linked to dairy products in Ethiopia and similar settings highlight significant risks posed by bacterial contamination. Several studies have identified pathogens such as *Escherichia coli*, *Salmonella spp.*, *Listeria monocytogenes*, and *Staphylococcus aureus* in raw milk and dairy products [12, 13]. Although specific outbreaks related to yogurt in Ethiopia are not well-documented, dairy product contamination in the region is common due to traditional handling practices and poor cold chain management [14, 15]. In similar African countries, *Staphylococcus aureus* contamination has led to food poisoning outbreaks, demonstrating the potential for such incidents in Ethiopia [16].

The consumption of contaminated yogurt poses several health risks. Pathogens like *Salmonella spp.*, *E. coli*, and *Listeria monocytogenes* can cause severe gastrointestinal infections, with symptoms such as diarrhea, vomiting, and fever [17]. These infections are particularly dangerous for vulnerable groups, including children, the elderly and immunocompromised individuals [18]. Furthermore, *Staphylococcus aureus* in yogurt can lead to food poisoning through its enterotoxins, causing nausea, vomiting, and abdominal pain [19]. Additionally, *Listeria monocytogenes* is a serious concern in refrigerated dairy products, as it can cause listeriosis, a life-threatening infection that poses particular risks to pregnant women [20].

Antimicrobial resistance (AMR) is another emerging concern in dairy products. Consuming yogurt contaminated with antimicrobial-resistant strains of bacteria, such as *E. coli* or *Salmonella*, complicates treatment of infections and increases the risk of severe outcomes [21]. This is particularly relevant in low- and middle-income countries like Ethiopia, where the prevalence of AMR is growing [22].

The safety and quality of yogurt products are critical concerns, especially in light of the rising consumer demand and the proliferation of commercial (branded) varieties [23]. Despite the importance of food hygiene indicators in evaluating these factors, comprehensive data on the microbiological quality of yogurt remains scarce, particularly regarding the presence of spoilage organisms [24]. Furthermore, food safety challenges in Ethiopia complicate these issues, including weak foodborne disease surveillance, inconsistent application of good manufacturing practices (GMP), inadequate law enforcement, and insufficient cooperation among stakeholders, all of which contribute to the risks associated with yogurt safety [6].

In Ethiopia, traditional yogurt production methods, which often lack adequate hygiene controls, increase the likelihood of contamination. The absence of pasteurization, combined with improper storage and transportation practices, contributes to the proliferation of harmful microorganisms [7, 25]. Limited cold chain infrastructure exacerbates the problem, especially in rural areas, where refrigeration is often unavailable [16]. Although Ethiopia has food safety regulations, enforcement remains inconsistent, particularly in informal markets where dairy products like yogurt are commonly sold [20]. The current food laws in the country are outdated and primarily focused on end-product inspection, lacking proactive methods for raw material and process control [10]. Indeed, the revision and appraisal of food laws should align with contemporary trends in the growth of commercially produced (branded) yogurt, based on data inputs from scientific research.

Additionally, no published reports have focused on coliform and yeast and mold enumerations in yogurt produced and commercialized in Ethiopia using the TEMPO system (bioMérieux). Chemical indicators, including pH levels, fat content, total solids (TS), solids-not-fat (SNF), ash content, and moisture content, are vital for understanding the stability and safety of yogurt products [9]. However, there is insufficient information on these physicochemical properties for both traditional (unbranded) and commercial (branded) yogurts. Thus, it is vital to evaluate the physicochemical properties and microbial quality of yogurt sold in Addis Ababa to determine its quality and perhaps safeguard the health and well-being of the numerous people consuming yogurt products.

Material and method

Study area

The study was carried out at Addis Ababa, the capital city of Ethiopia from February 2022 to May 2022 (altitude: 2350masl; average annual precipitation: 1143 mm; average annual temperature: 16.3 °C and located at 9° 1′48″N and 38° 44′ 24″E).

Sample collection

The method of processing of traditionally produced (ergo) was described previously by [3]. A total of 20 commercially produced (branded) yoghurt samples represent 5 different brands with 4 samples per brand were purchased from supermarkets using purposive sampling techniques. Concurrently, 20 traditionally produced (unbranded) yoghurt samples were collected through random sampling techniques from 20 different dairy shops. Commercially produced (branded) yoghurt samples (250 ml capacity) were purchased before its expiration date as indicated on the packaging materials, at the time of collection and analysis. Besides, 250 ml of traditionally produced (unbranded) yoghurt samples were collected aseptically in sterile screw-capped bottles from dairy shops. Strict aseptic procedures were followed when collecting yoghurt samples in order to prevent contamination. Yoghurt sample were labelled and transported to Animal Products, Veterinary Drug and Feed Quality Assessment Centre (APVD-FQAC), which is the quality control laboratory of the Veterinary Drug and Feed Administration and Control Authority (VDFACA) in Addis Ababa using an icebox containing ice pack (4^0C) within 3–4 h of collection. For ethical considerations, the samples were coded blindly throughout the study. This involved assigning a unique identification code to each sample at the time of collection, which was maintained throughout all stages of handling, analysis, and interpretation.

Physicochemical analyses

Moisture, ash, Total Solids (TS) and Solids-Non-Fat (SNF) content were determined by [26]. The pH of the yogurt samples was measured using a pH-meter (Corning Pinnacle, model 5A3i, Corning Incorporated, USA) while the fat content was determined using DA7250 perten NIR spectrophotometer scanning.

Microbial analysis

Total Bacterial Count (TVC) was conducted by the methods determined in [27] on pour plate of plate count agar (Oxoid) incubated at 30 °C for 72 h.

Coliform and yeast and mold counts were determined using TEMPO system (bioMérieux). Ten ml of the yoghurt samples were added into a sterile TEMPO bag containing 90 mL of sterile peptone water to prepare the first dilution and then homogenized in the TEMPO bag for 5 min. The culture medium was reconstituted by dispensing 3 ml of sterile distilled water (secondary diluent) in each vial. Then 0.1 mL of the homogenized mixture was transferred to the 3.9 mL of reconstituted media. It was mixed properly for approximately 30 s using a vortex-type mixer. The 4 mL of inoculated medium obtained corresponds to a 1/40 and 1:400 dilution of the sample (as recommended by the manufacturer as this dilution enables enumeration of bacteria between 10 and 4.9×10^4 cfu/mL for coliform and 100 and 4.9×10^4 cfu /mL for yeast and mold). One card for each vial of inoculated medium was removed from its protective covering, without touching the tip of the transfer tube. The vial containing the inoculated medium was put in the filling rack. The card was inserted in the slot opposite to the vial, placing the transfer tube of the card inside the vial. After giving the sample identification number in the TEMPO® software, the card was allowed to be filled up by the TEMPO® filler, which transfers the inoculated medium from the vial into the card that contains three sets of 16 wells (small, medium and large wells) with a one-log difference in volume for each set of wells (16×225; 16×22.5; and 16×2.25 μL). The cards were then removed from the filling station and incubated for 24–27 h at 35 ^{0}C for coliform and at 25 ^{0}C for 72 -76 h for yeast and mold count. The results were automatically analyzed by the software system that determines which of the wells tested positive. The number of positive wells obtained in relation to the volume of wells and the dilution of the samples, automatically allowed enumeration of the results in cfu/mL [28].

Statistical analysis

The physiochemical and microbial data of the yoghurt samples were analyzed using the General Linear Model procedure of the Statistical Analysis System Software (GLM, SAS, Version 9.1, 2008). Data from microbial counts were first transformed to logarithmic values (log10) before subjecting to statistical analysis. Each analyses were carried out in triplicate and the significant differences were determined at ($P < 0.05$).

Result

Physicochemical properties

The physicochemical properties of traditionally (unbranded) and commercially produced (branded) yoghurt samples are depicted in Table 1. In the traditionally produced (unbranded) yogurt samples, the fat content was 4.44%, pH 3.99, TS content 10.12%, SNF content 7.18%, moisture content 89.88%, and ash content 0.53%. For the commercially produced (branded) yogurt samples, the fat content was 5.02%, pH 3.88, TS content 10.66%, SNF content 8.10%, moisture content 89.29%, and ash content 0.62%.

Table 1 Physicochemical properties (Least square mean (± SE)) of traditionally and commercially produced yoghurt samples

Parameters	Yoghurt Types		*P*-value	T-test
	TPY	CPY		
	LSM ± SE	LSM ± SE		
Fat	4.44 ± 0.74%	5.02 ± 0.74%	0.582	0.31
Total solids	10.12 ± 0.35	10.66 ± 0.35	0.250	1.18
Solids Not Fat	7.18 ± 0.41%	8.10 ± 0.41%	0.120	2.53
PH	3.99 ± 0.06	3.88 ± 0.06	0.1957	1.734
Moisture	89.88 ± 0.36%	89.29 ± 0.36%	0.2518	1.354
Ash	0.53^b ± 0.023%	0.62^a ± 0.03%	0.0303	5.065

TPY Traditionally Produced Yoghurt, *CPY* Commercially Produced Yoghurt, *LSM* List Square Mean, *SE* Standard Error

Microbial quality

The TVC in traditionally and commercially produced yoghurt samples was found to be 10.72 and 10.35 $\log_{10}$ cfu/mL, respectively as depicted in Table 2. In terms of coliform counts (CC), 20%, 55%, and 25% of the traditionally produced yogurt samples had counts of < 10 cfu/mL, 10 to < 4.9×10^4 cfu/mL, and > 4.9×10^4 cfu/mL, respectively. For the commercially produced yogurt samples, 40%, 35%, and 25% fell within these same ranges. The overall mean coliform counts were 3.72 $\log_{10}$ cfu/mL for traditionally produced yogurt samples and 2.81 $\log_{10}$ cfu/mL for commercially produced yogurt samples; however, the difference was not statistically significant ($P > 0.05$) (Table 2). Similarly, for yeast and mold counts (YMC), 0%, 35%, and 65% of traditionally produced yogurt samples had counts of < 100 cfu/mL, 100—< 4.9×10^4 cfu/mL, and > 4.9×10^4 cfu/mL, respectively. In commercially produced yogurt, 30%, 50%, and 20% of samples fell within these same ranges. The overall mean YMC was 4.48 $\log_{10}$ cfu/mL for traditionally produced yogurt samples and 3.92 $\log_{10}$ cfu/mL for commercially produced yogurt samples, but this difference was also not statistically significant ($P > 0.05$) (Table 2).

Discussion

In our investigation, we observed that commercially (branded) produced yogurt had a numerically higher mean fat content (5.02 ± 0.74%) compared to traditionally

Table 2 Microbiological status (number, percent and Least square mean (± SE) (log10 cfu/mL)) of traditionally and commercially produced yoghurt samples

Count (cfu/ mL)	TPY			CPY		*P*-value	T-test
Coliform	N	Percent (%)		N	Percent (%)		
< 10	4	20		8	40		
> 4.9^*10^4	5	25		5	25		
10- < 4.9^*10^4	11	55		7	35		
LSM ± SE	3.72 ± 0.32			2.81 ± 0.39		0.0949	3.177
Yeast and Mold							
< 100	0	0		6	30		
> 4.9^*10^4	13	65		4	20		
100—< 4.9^*10^4	7	35		10	50		
LSM ± SE	4.48 ± 0.44			3.92 ± 0.39		0.8769	0.3649
	N		LSM ± SE			Min	Max
Total Viable Count	TPY20		10.72 ± 0.19			9.09	11.47
	CPY20		10.35 ± 0.16			9.32	11.48

N number of samples, *TPY* Traditionally Produced Yoghurt, *CPY* Commercially Produced Yoghurt, *SE* Standard Error produced (unbranded) yogurt samples (4.44 ± 0.74%) as depicted in Table 1. Higher fat content in commercially (branded) produced yogurt sample is often linked to its controlled manufacturing process, where full-fat milk or cream may be used to achieve a richer texture and more pronounced flavor [29, 30]. In contrast, traditionally produced (unbranded) yogurt sample, which is typically made from unstandardized raw milk, may exhibit variations in fat content due to the lack of milk standardization during processing [31]. The higher fat content in commercially (branded) produced yogurt sample might be contribute to a smoother, creamier mouthfeel, which enhances consumer appeal and satisfaction [32]. Additionally, the controlled conditions in commercial yogurt production allow manufacturers to fine-tune the fat content to meet specific quality and flavor standards, whereas traditionally produced yogurt is more dependent on the milk quality from smallholder farmers, resulting in lower and less consistent fat content [33]. Furthermore, fat content in yogurt plays a significant role in determining the overall caloric density, flavor intensity, and texture, making it an important factor for both product quality and consumer preference [34, 35]. Among both commercially (branded) and traditionally produced (unbranded) yoghurt samples, 25% did not comply with Ethiopian Standards [36]. According to US Code of Federal Regulations [37], yoghurt samples with more than 3.25% of fat content should be labelled yoghurt; yoghurt with fat content in the range of 0.5–2.0% should be labelled as Low-Fat yoghurt and yoghurt with less than 0.5% fat content should be labelled Non-Fat yoghurt. The results from our studies showed that the 75% and 70% of traditionally (unbranded) and commercially produced (branded) yoghurt samples, respectively were "yoghurt". Present values were higher than the result reported by [38–41] however, lower than the value reported by [42].

The total solids content of commercially produced (branded) yoghurt samples was 10.66% which is slightly higher than that of traditionally produced (unbranded) yoghurt samples (10.12%). The slightly higher total solids content of commercially produced (branded) yoghurt samples might be attributed to several factors associated with the manufacturing processes and ingredient selection. Commercial (branded) yogurt producers typically use whole milk or milk powder to enhance the total solids content, contributing to a thicker texture and improved mouthfeel [43]. In contrast, traditionally produced yogurt may utilize raw milk from smallholder farms, which can exhibit variability in composition due to differences in animal feed, breed, and overall milk quality [31, 32]. This variability may lead to lower total solids content in traditionally produced (unbranded) yoghurt samples, reflecting the natural composition of the raw milk used in its production. In contrast, the addition of stabilizers and thickeners is more common in commercial yogurt production, enhancing the texture and increasing the total solids content without compromising sensory attributes [44]. Traditionally produced (unbranded) yoghurt samples, on the other hand, relies on natural fermentation processes without the addition of these ingredients, which can result in lower total solids content [33]. The differences in processing techniques and ingredient selection between the two types of yogurt contribute significantly to their total solids content. The higher total solids content in yogurt may lead to improved sensory properties, such as creaminess and viscosity, making it more appealing to consumers [34, 35]. Higher percentage of total solids content was reported by [42] in Ethiopia.

The SNF content of commercially produced (branded) yoghurt samples in the current study complying the Ethiopian standard of 8.2% [36] as well as the standards set by East and Southern Africa[20] and the US Code of Federal Regulations[37], while traditionally produced (unbranded) yogurt samples did not comply with these limits, highlights significant differences in production practices and quality control measures between the two types of yogurt. Commercially produced yogurt often adheres to strict regulatory standards that ensure the nutritional quality and safety of the product [29, 30]. These standards require that yogurt contain a minimum amount of SNF to provide adequate protein, vitamins, and minerals, which are essential for consumer health [43]. The compliance of commercially produced (branded) yoghurt with the SNF standard indicates that manufacturers likely employ standardized processes and may use ingredients such as milk powder or whey protein concentrates to enhance the SNF content [45]. In contrast, traditionally produced (unbranded) yogurt samples may not follow the same rigorous quality control practices, as it is often made from raw milk sourced directly from smallholder farmers without standardization [31]. Variability in milk quality, influenced by factors such as animal feed, breed, and handling practices, can lead to inconsistencies in the SNF content of traditionally produced (unbranded) yogurt samples [32, 34]. Additionally, traditional fermentation processes may not effectively concentrate solids, resulting in lower SNF levels that fail to meet regulatory standards [33]. The failure of traditionally produced (unbranded) yogurt samples to comply with SNF standards raises concerns about the nutritional adequacy and quality of these products, especially given the increasing consumer demand for safe and healthy food options [35]. Additionally traditionally produced (unbranded) yogurt samples did not comply with these limits in the current study reflects broader issues related to quality control, ingredient standardization, and consumer safety in the yogurt market [29, 43].

In the present research the pH value of both commercially produced (branded) and traditionally produced (unbranded) yogurt samples did not fall within the acceptable commercial manufacturing standards of 4.0 to 4.6 indicates potential quality control issues and raises concerns about the fermentation processes used in both types of yogurt production. pH is a critical parameter in yogurt production, as it affects not only the flavor and texture of the yogurt but also its shelf life and safety. A pH value below 4.6 is generally required to inhibit the growth of pathogenic microorganisms, ensuring the safety of the product [43]. The pH of yogurt remains above this threshold, it may suggest inadequate fermentation or insufficient activity of lactic acid bacteria, which are responsible for acidifying the milk during the fermentation process [29]. For commercially produced yogurt, failing to achieve the desired pH range could be attributed to various factors, including suboptimal starter culture selection, fermentation time, or temperature [31]. It may also indicate inconsistencies in the quality of raw milk, which can impact the fermentation process and result in higher pH values [34]. Manufacturers often implement rigorous quality control measures to ensure pH consistency; thus, a consistent deviation from established standards may reflect broader systemic issues in the manufacturing process [45]. On the other hand, for traditionally produced yogurt, the failure to achieve the required pH may be even more pronounced due to the lack of controlled fermentation conditions, as traditional methods often rely on spontaneous fermentation without standardized processes [30]. Variability in milk composition and fermentation times can lead to inconsistent acid production, resulting in a higher final pH [32]. The implications of both types of yogurt failing to meet pH standards are significant. A higher pH can compromise the safety of the yogurt by allowing the growth of undesirable microorganisms, thus posing health risks to consumers [44]. Moreover, it can affect consumer acceptance, as the texture and flavor associated with lower pH values are often preferred [35]. The failure of both yogurt samples to meet the pH standards reflects potential issues in production processes, quality control, and fermentation practices, highlighting the need for improvements in both commercial and traditional yogurt production methods to ensure consumer safety and product quality [29, 43]. The mean pH values in this study was lower than the values reported by [39, 42].

The mean moisture content of traditionally (unbranded) and commercially produced (branded) yoghurt samples in the current study did not conform to the moisture content as reported by [46] raises important concerns regarding the quality and safety of these products. Moisture content is a critical parameter in yogurt production, as it affects the texture, flavor, and shelf life of the final product. High moisture levels can lead to a shorter shelf life and increased susceptibility to microbial spoilage, while lower moisture levels may contribute to a creamier texture and longer shelf stability [43]. Generally, commercial standards dictate specific moisture content ranges to ensure product consistency and quality, often falling between 80 and 85% for yogurt [29]. For commercially produced (branded) yoghurt samples, non-compliance with moisture content standards could indicate a lack of quality control during manufacturing processes. Factors such as the use of improper ratios of milk and other ingredients, inadequate processing techniques, or poor storage conditions can contribute to variations in moisture content [31]. If the moisture content exceeds the recommended levels, it can result in a yogurt that is too thin or watery, impacting consumer acceptance and overall sensory attributes [45]. In the case of traditionally (unbranded) produced yogurt sample, the failure to meet moisture content standards may be more pronounced due to the absence of standardized production practices. Traditional yogurt production often relies on spontaneous fermentation, which can lead to variability in moisture content depending on factors such as fermentation time, temperature, and the quality of the raw milk used [30]. The lack of control over these variables can result in inconsistencies in the final product, making it difficult to achieve the desired moisture levels [34]. Both traditionally (unbranded) and commercially produced (branded) yoghurt samples do not conform to moisture specifications may pose health risks to consumers due to increased microbial growth potential, particularly in the case of traditional yogurt, where safety measures may already be lax [32]. Moreover, the commercial viability of yogurt products can be affected, as consumers tend to favor products that meet their expectations in terms of texture and flavor [35]. The failure of both traditionally (unbranded) and commercially produced (branded) yoghurt samples in the current study to meet moisture content standards indicates a need for improved quality control and production practices in both sectors. Addressing these issues is crucial for ensuring consumer safety and satisfaction, as well as maintaining the integrity of yogurt as a healthy food option [29, 43].

The ash content of traditionally produced (unbranded) yoghurt samples were significantly ($p < 0.05$) lower than that of commercially produced (branded) yoghurt samples as presented in Table 1. The significant difference in ash content between traditionally produced (unbranded) and commercially produced (branded) yogurt samples can be explained by several factors related to production methods, ingredient quality, and processing practices. Ash content represents the total mineral content in yogurt, which includes essential minerals such as calcium, magnesium, phosphorus, and potassium. These minerals are critical for various physiological functions in the human body, including bone health and metabolic processes [47]. Higher ash content is often associated with better nutritional quality, making it an important indicator for yogurt products [48]. Additionally, commercially produced (branded) yoghurt samples in the current study might may fortified with minerals or contain added ingredients designed to enhance nutritional value, which can contribute to increased ash content [49]. In contrast, traditionally produced (unbranded) yoghurt samples traditionally produced yogurt usually relies on raw milk obtained from smallholder farmers, who may not have access to optimal feeding or farming practices. The variability in mineral content of the raw milk used can lead to lower ash content in the final product [45]. Moreover, traditional production methods often lack the fortification practices that are more common in commercial production [50]. Furthermore, the production practices of commercially produced yogurt often employ standardized techniques, which help maintain consistent mineral content across batches. Factors such as pasteurization, controlled fermentation, and the use of specific starter cultures can contribute to a more stable mineral profile in commercially produced (branded) yoghurt samples [43]. Conversely, traditional yogurt production may involve spontaneous fermentation, leading to greater variability in the final product's mineral composition [30]. The lower ash content in traditionally produced (unbranded) yoghurt samples in the current study suggests that these products may offer less in terms of essential minerals, which could impact consumer health, especially for populations that rely on yogurt as a key dietary source of calcium and other minerals [51]. The lower ash content traditionally produced (unbranded) yoghurt samples in the current study highlights the need for improved quality control measures in traditional yogurt production to enhance the mineral content and overall quality of these products [31]. The mean ash content of the traditionally (unbranded) and commercially produced (branded) yoghurt samples is lower than those reported by [38, 40, 42]. However, it is comparable with the result reported by [36].

In the present study, traditionally produced (unbranded) yogurt samples exhibited a TVC of 10.72 $\log_{10}$ cfu/mL, while commercially produced (branded) yogurt samples had a slightly lower TVC of 10.35 $\log_{10}$ cfu/mL. Traditionally produced (unbranded) yogurt samples are often prepared through spontaneous fermentation in uncontrolled settings, which leads to higher TVC. In contrast, commercial yogurt is produced in controlled environments following strict hygiene and safety standards, reducing contamination risks and resulting in lower TVC. Additionally, traditional fermentation relies on natural processes, which can foster the growth of both beneficial and harmful microorganisms, further contributing to elevated TVC [52]. The quality of raw milk also plays a significant role, resulting in higher initial TVC. Interestingly, branded yogurt may also exhibit higher TVC due to the use of starter cultures, mainly lactic acid bacteria. The standard aerobic bacterial count for yogurt is 10^6 – 10^7 cfu/mL, equivalent to 6–7 $\log_{10}$ cfu/mL [52, 53]. Therefore, the results of this study reveal TVC significantly exceeding standard values, which could be indicative of post-pasteurization contamination, possibly resulting from inadequate hygiene during production [52]. In most food products, TVC is a key indicator of sanitary quality, safety, and utility, reflecting factors such as raw material contamination, processing efficiency, and the cleanliness of equipment and utensils [52]. Poor storage conditions or extended storage times can also contribute to elevated TVC [54]. This underscores the urgent need to raise awareness among yogurt producers about improving hygiene practices during production. High TVC can signal spoilage and the presence of harmful microorganisms that pose health risks, aligning with consumer safety concerns and regulatory standards in the context of public health. The study's findings are higher than those reported by previous studies [38]but align with findings from [39].

The coliform count (CC) is a crucial microbiological indicator for assessing yogurt's sanitary quality. Elevated CC levels in both traditionally produced (unbranded) (3.72 $\log_{10}$ cfu/mL) and commercially (branded) produced yogurt samples (2.81 $\log_{10}$ cfu/mL) suggest poor hygiene practices and inadequate sanitation during or after production. This may also indicate insufficient preheating, particularly in commercial brands expected to maintain higher quality standards. Coliform counts are commonly used by public health authorities to indicate hygiene failures or post-processing contamination in dairy products. According to Food Standards Australia New Zealand (FSANZ) [55] regulations, only 20% of traditional and 40% of commercial yogurt samples in this study met safety standards. The higher CC in traditionally produced (unbranded) yogurt sample is largely due to informal production methods, which often lack standardized hygiene protocols, leading to increased contamination risks, especially when raw milk is used [52]. While commercial yogurt is generally produced in regulated facilities with better hygiene practices, the presence of higher CC in some commercially (branded) produced yogurt sample may reflect inconsistent application of good manufacturing practices (GMP). Most dairy processing plants in Ethiopia source milk from smallholder farmers, where food safety standards are often insufficient [7], which can directly impact the CC of commercially produced (branded) yogurt samples. The study reveals concerning levels of non-compliance with FSANZ [55] standards for both yogurt types. High coliform counts, often linked to fecal contamination, pose public health risks due to potential exposure to pathogens that cause foodborne illnesses [52]. Traditional produced yogurt's reliance on spontaneous fermentation can promote the growth of both beneficial and harmful microorganisms, resulting in higher CC levels. High coliform counts in traditionally produced yogurt pose health risks, especially in populations that rely on these products as dietary staples. This is particularly concerning given that traditionally produced yogurt is often consumed without further cooking or processing, which could expose consumers to pathogenic bacteria. These findings underscore the urgent need for improved hygiene and quality control, both commercially produced (branded) and traditionally produced (unbranded) yoghurt samples, to ensure food safety and protect public health. The current finding of CC is comparable to the value reported by [42] from traditionally (unbranded) produced yoghurt sample and lower than laboratory made cow milk yoghurt.

The yeast and mold count (YMC) is a crucial indicator of the microbiological quality and safety of yogurt, reflecting its overall freshness and potential for spoilage. In the current study, the YMC for traditionally produced (unbranded) yoghurt samples was 4.48 log10 cfu/mL, while the commercially produced (branded) yoghurt samples had a lower count of 3.92 log10 cfu/mL. Muluken et al. [42] observed that the mean YMC were 8 log and 3.93 log_{10} cfu/mL, respectively. Additionally, only 30% of the commercially produced (branded) yoghurt samples complied with the standards set by Food Standards Australia New Zealand (FSANZ) [55]. The higher YMC observed in traditionally produced (unbranded) yoghurt samples can be attributed to the uncontrolled production conditions and methods typically used by smallholder farmers. Traditionally produced (unbranded) yoghurt samples often undergoes spontaneous fermentation in environments that may not be sanitary, which can promote the growth of yeast and molds, leading to elevated counts [56, 57]. Furthermore, the shelf life of yogurt is significantly impacted by YMC, as high levels can lead to spoilage and undesirable sensory changes. Only 30% of commercially produced (branded) yoghurt samples complied with FSANZ standards [55] indicates that some products still exhibited higher YMC than acceptable limits, potentially due to inadequate processing, improper storage conditions, or contamination during distribution [58, 59]. Consumer expectations and market demand for high-quality yogurt also influence compliance with food safety standards. Manufacturers are increasingly aware that consumers prefer yogurt with lower yeast and mold counts, as elevated levels can indicate spoilage or poor production practices [60]. Meanwhile, the high YMC in traditionally produced (unbranded) yoghurt samples raises concerns about its safety, particularly for immune-compromised individuals who may be more susceptible to foodborne illnesses caused by these microorganisms [61]. The current finding highlight the urgent need for improved quality control in both traditionally produced (unbranded) and commercially produced (branded) yoghurt samples. Until this moment, there are no published studies focusing on CC and YMC in Yoghurt produced and commercialized in Ethiopia with TEMPO system (bioMérieux), being impossible to broad comparison of the results obtained.

Conclusion

In general, the current finding underscore the need for enhanced quality control and food safety measures in both commercially produced (branded) yoghurt and traditionally produced (unbranded) yoghurt to ensure consumer health and compliance with established standards. Overall, these findings emphasize the importance of ongoing monitoring and assessment of yogurt quality to safeguard public health.

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Authors' contributions

The work reported in this manuscript was a component of a wider MSc study for M.F. T.W. and U.G. were the university supervisors of the candidate. M.F. contributed to the writing of the research proposal and data collection. T.W. prepared the study design, data analysis and interpretation, and manuscript writing. U.G. contributed to research proposal writing and manuscript editing. All authors reviewed and agreed on the final draft of the manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

The work did not involve experimental animals or human subjects. As such it was exempted from institutional ethical clearance.

Consent for publication

In our study, we don't have any images or videos, etc. of individual participants.

Competing interests

The authors declare no competing interests.

Author details
[1]College of Agriculture and Environmental Sciences, School of Animal and Range Sciences, Haramaya University, P. O. Box 138, Dire Dawa, Ethiopia. [2]Ministry of Agriculture, Addis Ababa, Ethiopia. [3]Ethiopian Institute of Agricultural Research, Holeta Agricultural Research, Holeta, Ethiopia.

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