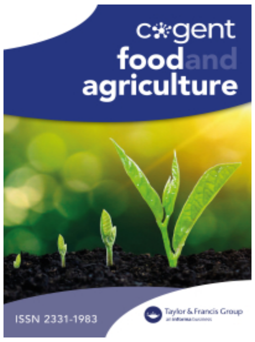

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Physico-chemical and microbiological quality of raw milk produced by smallholder farmers in Gulu City, Northern Uganda

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ABSTRACT
Smallholder dairy farmers in Northern Uganda sell raw milk to the final consumers without conducting quality control measures. This study evaluated physico-chemical and microbiological quality of milk produced by smallholder farmers in Gulu City. Samples of raw milk were collected from forty (40) smallholder dairy farmers rearing lactating exotic breed of dairy cows (Holstein Friesian) in zero grazing units and eight (8) from milk collection centers. Data were analyzed in SPSS software (version 21.0) by employing descriptive statistics, one-way ANOVA and *t*-test to separate significant means at 5% level of significance. Significant ($P<0.05$) differences were observed in the content of solid-not-fat (SNF), specific gravity, pH value, lactic acid, Coliform count and total plate count of colony forming unit among four divisions in Gulu City. There was no discernible ($p>0.05$) difference in protein as well as fat content for milk sampled from the study divisions. In conclusion, smallholder dairy farmers in Gulu City conduct limited recommended key practices for raw milk production leading to compromised microbiological and physico-chemical quality. Further research is needed on in-depth analysis of the different species of micro-organisms in raw milk from both local and exotic breeds of dairy cattle under the smallholder farming system in Northern Uganda.

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Introduction

Dairy cattle are considered as the major source of fresh milk and milk products for human consumption worldwide (Lokuruka, 2016). The dairy industry is amongst the fastest growing food sectors when considering sales, volume output, and commodity prices which makes it to play a significant role in the economics and nutrition of many stakeholders ranging from farmers to milk vendors, processors, and the final consumer (Kurwijila, 2006). In sub-Sahara Africa (SSA), over 90% of raw milk comes from the smallholder sector to meet the increasing demand for milk and milk product consumption amongst the growing population (Ekou, 2014). According to Muriuki (2011), the raw milk market presents several difficulties concerning standards and quality control, as well as related health and safety issues but consumers find it a low-cost option while still offering higher prices to producers who do not have to invest in processing.

Despite the growing demand of milk for human consumption, raw milk quality from smallholder dairy farmers remains poor which poses threat on human health and known to be potential sources of zoonotic diseases especially brucellosis, tuberculosis, mastitis- related enterotoxaemia amongst others (Kivaria et al., 2006). Commonly, raw milk is collected using plastic containers which presents difficulty in thoroughly cleaning and disinfecting, leading to microbial growth as compared to using aluminum cans (Gemechu et al., 2015; Orregård, 2013). This results in less hygienic milk handling and deterioration of quality of milk supplied by smallholder farmers. Coupled with the growth of common micro-organisms such as *Listeria monocytogenes, Salmonella species,* and *Staphylococcus aureus* in raw milk which are associated with food poisoning, the presence of these pathogens in raw milk presents a major public health concern to consumers of milk and dairy products (Lingathurai et al., 2009).

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Observation of Hazard Analysis Critical Control Point (HACCP) management system by smallholder dairy farmer are recommended to be followed for raw milk quality realization and addressing food safety concerns (Te-Giffel, 2003). This should include analyzing and controlling biological, physical and chemical hazards from the point of production to the consumption of finished product.

Due to the fact that large amounts of milk that is marketed unprocessed, and that there may be weak monitoring of the market, the raw milk collection and bulking enterprises in Northern Uganda experience critical quality control challenges including adulteration (both water and preservatives), high bacterial load due to warm collection, the potential for contamination with coliforms due to handling and presence of anti-microbial residues (Muriuki, 2011). Efforts have been made to preserve milk, particularly for commercial purposes by pasteurization and Ultra heat treatment (UHT) which prolonged its days for safe consumption within a period of seven days for pasteurized milk and six months for UHT milk (BSTI 2002 BDS 1702 2002). However, poor milk quality at farm level, faults in processing, and problems in preservation at the consumer side may result into microbial contamination in milk and increase chances of deterioration of milk much before the recommended preservation time (Elmagli & El Zubeir, 2006; Hassan et al., 2009). Thus, the initial poor quality from smallholder farmers compromises the preservation effort later in the supply chain. Notably, urban smallholder dairy farmers in the Gulu City of Northern Uganda are not carrying the key recommended practices required for producing good quality raw milk for human consumption which expose consumers to contaminated milk. This study therefore assessed the quality of raw milk from smallholder farming systems in the Gulu City of Northern Uganda by analyzing microbial load and other chemical parameters in the samples.

Methods

Study site

The study sampled milk from the four divisions (Pece, Laroo, Bar-dege, and Layibi) of Gulu City (formerly Gulu Municipality). The divisions were purposively selected because of the high number of smallholder dairy farmers with lactating exotic breed of dairy cows (Holstein Friesian) in a zero-grazing unit. An estimated 200 households were keeping 1600 dairy cattle in the study area (GDDP, 2016). The region experiences an average rainfall of 1,500 mm per year, with monthly average ranging from14 mm in January to 230 mm in August. According to Nabukenya et al. (2014), the wet season typically lasts until October, with May, August and October seeing the most rainfall.

Design of the study

A completely randomized design (CRD) was employed to collect forty-eight (48) samples of raw milk in a quantity of half (0.5) liter per sample from 40 smallholder dairy farmers of lactating exotic breed (Holstein Friesian) and 8 milk collection centers (also collect milk from farmers). The cows were under intensive system of zero-grazing method and fed ad libitum on nappier grass, calliandra sessbania, banana peeling and, mineral licks amongst others.

The milk samples were hygienically collected and transported to the laboratory for analysis following the steps described by Oliver et al. (2004). Using a permanent marker, new label sample tubes were acquired with date, cow identification number, and location where the milk was collected from. The sample tubes were kept closed until the sample were collected. Sample tubes were immediately opened before the samples were taken. Hands were not allowed to come into contact with the inside of the tube, including the lid. Milk was then collected until the sample tube was approximately ½ full, the tube was immediately closed once filled. The milk sample in the tubes were immediately placed in a cooler box, vacuum sealed at approximately 4 °C and transported to the laboratory for analysis.

Laboratory analysis procedure

The milk pH

Hanna Instruments HI 8424 Digital pH meter (Leighton Buzzard, UK) was used to measure the pH of the sampled raw milk as applied in the study of On-Nom et al. (2010). The standard of pH 4 and 7 (VWR International Ltd., Poole, UK) was used to calibrate the pH probe.

Specific gravity

Using hydrometer calibrated to quantify immunoglobin (Ig) in colostrum milk, specific gravity of the sampled milk was measured using the regression equation, and the measurement was taken at about 37 °C (Fleenor & Stott, 1980).

Determination of protein

Using the standard Macro-Kjeldahl method, the protein value of the samples was determined. In this method, the milk samples were digested with concentrated Sulphuric acid (H_2SO_4) to release nitrogen which was determined by a suitable titration technique (Didier & Sylvie, 2018). The estimated amount of protein present was then determined from the nitrogen (N_2) concentration of the sampled milk (AOAC, 2016).

Determination of fat

Using Gerber method, the fat content of the samples was evaluated. The samples were added to Gerber butyrometer containing $H_2SO_{4.}$ Isoamyl alcohol was then added into butyrometer and the content was vigorously mixed in order to dissolve the curd and ensure fat is released. The released fat was then isolated by centrifugation and quantified in the graduated portion of the Gerber butyrometer (Kleyn et al., 2001).

Determination of solid not fat (SNF)

The gravimetric method was applied to assess solid not fat content of the milk samples, which involved weighing the milk samples, drying and weighing the dried residue. The total solid content of the milk was then weighed and expressed as a percentage of the original milk weight (McDowell, 1972).

Determination of titratable acidity of milk (lactic acid)

This was determined by adding 3 drops of 1% phenolphthalein indicator to about 10 ml of the milk sample in a conical flask following the Association of Official Analytical Chemists method (AOAC, 1990; Gemechu et al., 2015). This was followed by titration with 0.1NNaOH solution of the milk sample to form persistent faint pink color. Using the formula below, titratable acidity was determined and expressed as % lactic acid;

$$\text{Titratable acidity}(\%) = \frac{\text{Ml} \times \text{N} \times 90 \times 100}{\text{V} \times 1000}$$

Where:
Ml = Quantity of 0.1 NaOH used
N = Normality of 0.1 N NaOH
V = Quantity of milk solution used.

Determination of total bacterial count

The was determined using plate count agar method as described by Gemechu et al. (2014) where 0.1 ml sample of milk was transferred into 45 °C cooled agar, added and mixed thoroughly with 0.9 ml of peptone water and 10^{-5} serial dilution. At 32 °C for 48 hours, the surface plated duplicate decimal dilutions of milk samples were incubated on standard plate count agar for total bacterial count. The results of colony formed on each Petri dish was counted, recorded and converted into Log 10 and reported in cfu/ml using the formula below;

N= C/vd Where:
C: Colonies counted in a plate
v: The quantity of sample applied on the plate
d: The dilution which the count was obtained.

Determination of coliform count

By using the Violet Red Bile Agar (VRBA) method, which involved cooling VRBA to 45 °C, 0.1 ml of milk sample was put to a sterilized epidoff tube containing 0.9 ml of peptone water and a serial dilution of 10^{-4}, and the mixture was thoroughly mixed, the coliform count was determined (Gemechu et al., 2014). After that, the surface plating was incubated at 37 °C for 24 before counting and recording established colonies that grew in each Petri dish. The data were then converted to Log 10 and reported in the form of cfu/ml using the formula below;

$$\text{N} = \text{B} / \text{dv}.$$

Where:
B: is the total number of colonies counted in a plate
v: is the volume of sample applied on the plate
d: is the dilution from which the count was obtained.

Statistical analysis

Data obtained were analyzed using Statistical Package for the Social Sciences (SPSS) software, version 21.0 by applying descriptive statistics involving means and standard deviation. One-way analysis of variance was used to test variation in milk quality parameters among the four study divisions while an independent *t*-test was generated to measure differences between the samples from farmers and those from the milk collection center. All analyses were done at 5% level of significance ($p < 0.05$).

Results and discussions

The physico-chemical quality of raw milk produced by smallholder dairy farmers

Results indicated that solid not fat, specific gravity, pH value, and titratable acidity (lactic acid) contents of the milk varied significantly for samples from the different divisions of Gulu city (Table 1). Protein and fat content, however, did not vary significantly ($p \geq 0.05$) across the study sites. The content of solid not fat was generally higher in milk samples from the dairy farmers in the area of Laroo, Bar-dege and Pece Division as compared to farmers from Layibi Division. The significant variation in the content of solid not fat, specific gravity, pH value and lactic acid could be due to variation in milk handling practices and animal husbandry management practices (especially feeding lactating cow) amongst farmers which might have affected the milk constitution. This suggests that, though smallholder dairy farmers in urban areas are knowledgeable on clean milk production, majority may not have been following the recommended standard practices for hygienic milk handling procedures. In addition, they could have frequently adulterated milk by adding water, cooking oil, cassava filtrates in order to increase milk' volume thereby, decreasing its quality for human consumption and providing a good medium for microbial growth. This is in line with with Dey and Karim (2013) who reported that, decrease in the specific gravity of the milk could be due to addition of water or cooking oils (fat) as opposed to removal of fat. The addition of additives (water, cooking oil and others) as a way to increase milk volume also affects specific gravity and provides medium for bacterial growth. In a similar study, Samia et al. (2009) also reported 8.43% of SNF content in raw milk of dairy cows reared along the Blue Nile in Sudan similar to 8.45% from our current study. Our study, however, contradicts O'Connor's (1995) findings, which stated that the typical titratable acidity of fresh raw cow milk varied between 0.14 and 0.16% as ours ranged from 0.28 to 0.31%. Additionally, the pH of the raw milk sample was found to be somewhat lower (6.59) in the study of Debela and Eshetu (2015) and Abeygunawardana and Deshapriya (2017) than it was in the current study (6.67).

Microbiological quality of raw milk produced by smallholder dairy farmers

Generally, the current study indicated that raw milk produced by smallholder urban dairy farmers contains high quantity of bacterial counts (Table 2). There was a significant ($p \leq 0.05$) difference observed in the raw milk samples' coliform count and total plate count across the four divisions of Gulu City.

The results suggest that majority of the smallholder urban dairy farmers do not handle milk hygienically, which results in contaminated raw milk that is unsafe for human consumption Furthermore,

Table 1. Variation in the physico-chemical properties of raw milk sampled from smallholder dairy farmers in four divisions of Gulu City, Northern Uganda.

Physico-chemical qualities	Layibi	Laroo	Bar-dege	Pece	P-value
Protein (%)	3.165 ± 0.054	3.172 ± 0.035	3.259 ± 0.033	3.216 ± 0.035	0.325
Fat (%)	4.881 ± 0.135	4.618 ± 0.058	4.845 ± 0.100	4.636 ± 0.063	0.101
Solid not fat (%)	8.284 ± 0.033^a	8.559 ± 0.065^b	8.412 ± 0.059^c	8.551 ± 0.027^d	0.000
Specific gravity	1.027 ± 0.000^a	1.027 ± 0.001^b	1.026 ± 0.001^c	1.025 ± 0.000^d	0.000
pH Value	6.662 ± 0.018^a	6.681 ± 0.008^b	6.673 ± 0.010^c	6.656 ± 0.008^d	0.000
Titratable Acidity (% LA)	0.231 ± 0.002^a	0.230 ± 0.002^b	0.228 ± 0.002^c	0.230 ± 0.001^d	0.000

Means within a row with different superscripts differ significantly ($p \leq 0.05$)

Table 2. Variation in the levels of microbiological counts (log10 cfu/ml) of raw milk sampled from four divisions of Gulu City in Northern Uganda.

	Sample location (division and milk collection center)					
Bacterial group	Layibi	Laroo	Bar-dege	Pece	collection center	p-value
Total plate count (log cfu)	5.760 ± 0.038	5.820 ± 0.051	5.761 ± 0.048	5.644 ± 0.080	6.315 ± 0.082	0.000
Coliform count (log cfu)	4.332 ± 0.038	4.382 ± 0.049	4.319 ± 0.029	4.242 ± 0.061	4.904 ± 0.036	0.000

the majority of the raw milk sale locations have a few stringent quality control procedures in place. Cross contamination during milking, storing or transporting operation to the retail location may be the cause of the increased total bacterial plate counts at the milk collection centre. This could be as a result of improper cold chain facilities at the collection centre due to frequent power blackout, poor handling, uncleaned cow's udder or dirty milk storage utensils which couples with poor practices like adding water, cooking oil and cassava filtrates which compromise milk' quality. This suggestion is in line with the findings of Negash et al. (2012), who stated that a high coliform count in raw milk may be a sign of Escherichia coli (E. coli) due to faecal contamination of improperly clean, sanitized and dried equipment. In a related study conducted by Neema (2016), also found that fresh raw milk from cow contains some bacteria and somatic cells, which make up the biological components of the milk. These components are subject to change based on various production parameters, including the health of the cow, cleanness standard during milking, and milk storage and transportation. Furthermore, fresh and raw dairy milk were shown to have larger amount of bacterial burdens, according to Tassew and Seifu, (2011) and Rahamtalla *et al.* (2016). The current study's 5.1479 $\log_{10}$ cfu/ml bacterial count is higher than 1.24 $\log_{10}$ cfu/ml reported by Mesfine et al. (2015) in raw milk from Dire Dawa City, Eastern Ethiopia. The difference in the two sets of results may be due to differences in environmental factors, feeding and milk handling practices which are likely to vary between Eastern Ethiopia and Northern Uganda.

Conclusion

The physico-chemical properties of milk produced by the smallholder urban farmers in Gulu City of Northern Uganda are poor which poses a risk to human health when consumed unprocessed or with poor processing techniques. There is need to ensure that the quality of milk produced and supllied in the city meet the recommended East African Standards (EAS) and Uganda National Bureau of Standards (UNBS) on raw and whole milk. In addition, there is limited capacity to check and maintain acceptance levels of the microbiological quality of raw milk. Further study should be conducted on an in-depth analysis of different species of micro-organisms present in raw milk produced by urban and per-urban smallholder dairy farmers to guide quality monitoring effort.

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Disclosure statement

The authors state that there was no conflict of interest with relation to this article's publication.

About the authors

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Data availability statement

The study related data can be made available upon request.

References

Abeygunawardana, D., & Deshapriya, R. (2017). Hygienic practices and quality of raw milk produced in a small-scale dairy farming area in Sri Lanka. *International Journal of Scientific and Research Publications*, *7*(7), 1–6.

AOAC. (1990). In K. Helrich (Eds.). *Official methods of analysis* (15th ed., Vol. 1).

AOAC. (2016). *Official methods of analysis of AOAC INTERNATIONAL*. (20th 636 ed.). Association of Official Analytical Chemists.

BSTI 2002 BDS 1702. (2002). *Bangladesh standard: Specification for pasteurized milk* (pp. 2–3). Bangladesh Standards and Testing Institution, Tejgaon Industrial Area.

Debela, T. G., & Eshetu, M. (2015). Physico-chemical qualities of raw cow milk in Ethiopia. The case of Borana zone, Yabello District. *Global Journal of Dairy Farming and Milk Production*, *3*(2), 86–91.

Dey, S., & Karim, M. H. (2013). Study on physicochemical and microbial quality of available raw, pasteurized and uht milk during preservation. *International Journal of Science Inventions Today*, *2*(2), 150–157.

Didier, D., & T. C., Sylvie, P. (2018). *Milk proteins - Analytical methods*. *Reference module in food science*. Academic Press. 9780081005965. ff10..1016/B978-0-08-100596-5.22616-4ff. ffhal-02267859f

Ekou, J. (2014). Dairy production and marketing in Uganda: Current status, constraints and way forward. *African Journal of Agricultural Research*, *9*(10), 881–888.

Elmagli, A. A. O., & El Zubeir, E. L. (2006). Study on the compositional quality of pasteurized milk in Khartoum State (Sudan). *International Journal of Dairy Sciences*, *1*(1), 12–20.

Fleenor, W. A., & Stott, G. H. (1980). Hydrometer test for estimation of immunoglobulin concentration in bovine colostrum. *Journal of Dairy Science*, *63*(6), 973–977. https://doi.org/10.3168/jds.S0022-0302(80)83034-7

GDDP. (2016). Gulu District Local Government, second five years District Development Plan 2015/2016 – 2019/2020 (issue March 2016).

Gemechu, T., Beyene, F., & Eshetu, M. (2014). Handling practices and microbial quality of raw cow milk produced and marketed in Shashemene Town. *Academic Journals*, *2*(9), 153–162.

Gemechu, T., Beyene, F., & Eshetu, M. (2015). Physical and chemical quality of raw cow's.

Hassan, A., Amjad, I., & Mahmood, S. (2009). (2009). Microbiological and physicochemical analysis of different UHT milk available in local market. *As. J. Food Ag-Ind*, *2*(03), 434–447.

Kivaria, F. M., Noordhuizen, J. P. T. M., & Kapaga, A. M. (2006). Evaluation of the hygienic quality and associated public health hazards of raw milk marketed by smallholder dairy producers in the Dar es Salaam region, Tanzania. *Tropical Animal Health and Production*, *38*(3), 185–194. https://doi.org/10.1007/s11250-006-4339-y

Kleyn, D. H., Lynch, J. M., Barbano, D. M., Bloom, M. J., Mitchell, M. W., Cooper, L. S., Cusak, E., Fick, M., Hanks, T., Hesen, M. K., Johnson, J., Kleyn, D. H., Mercer, F., Monahan, D., Peat, B., & Petit, M. (2001). Determination of fat in raw and processed milks by the Gerber method: collaborative study. *Journal of AOAC International*, *84*(5), 1499–1508. https://doi.org/10.1093/jaoac/84.5.1499

Kurwijila, L. R. 2006. *Hygienic milk handling, processing and marketing. Reference guide for training and certification of small-scale milk traders in East Africa* (Vol. 1).

Lindmark-Månsson, H., Fondén, R., & Pettersson, H.-E. (2003). Composition of Swedish dairy milk. *International Dairy Journal*, *13*(6), 409–425. https://doi.org/10.1016/S0958-6946(03)00032-3

Lingathurai, S., Vellathurai, P., Vendan, S. E., & Anand, A. A. P. (2009). A comparative study on the microbiological and chemical composition of cow milk from different locations in Madurai, Tamil Nadu. *Indian Journal of Science and Technology*, *2*(2), 51–54. https://doi.org/10.17485/ijst/2009/v2i2.11

Lokuruka, M. N. I. (2016). Overview of dairy processing and marketing in East African dairy value chains: Opportunities and challenges. *African Journal of Food Science*, *10*(11), 254–262.

McDowell, A. K. R. (1972). A comparison of various methods for the estimation of solids-not-fat in milk and whey. *Journal of Dairy Research*, *39*(2), 251–259. https://doi.org/10.1017/S0022029900014084

Mesfine, S., Feyera, T., & Mohammed, O. (2015). Microbiological quality of raw cow' s milk from four dairy farms in Dire Dawa City. *Eastern Ethiopia*, *10*(1), 9–14.

Muriuki, H. G. (2011). *Dairy development in Kenya*. Food and Agricultural Organization of the United Nation.

Nabukenya, I., Akiiki, C. R., Olila, D., Ikwap, K., & Höglund, J. (2014). Ethnopharmacological practices by livestock farmers in Uganda: Survey experiences from Mpigi and Gulu districts. *Journal of Ethnobiology and Ethnomedicine*, *10*(1), 1–14. https://doi.org/10.1186/1746-4269-10-9

Neema, J. M. (2016). *Microbiological and compositional quality of raw milk delivered by small scale dairy farmers to the milk collection centre in Hai district, Tanzania*. University of Zimbabwe.

Negash, F., Tadesse, E., & Woldu, T. (2012). Microbial quality and chemical composition of raw milk in the Mid-Rift Valley of Ethiopia. *African Journal of Agricultural Research*, *7*(29), 4167–4170.

O'Connor, C. B. O. (1995). *Rural dairy technology (Issue January)*. International Livestock Resaerch Institute.

Oliver, S. P., Gonzalez, R. N., Hogan, J. S., Jayarao, B. M., & Owens, W. E. (2004). *Microbiological procedures for the diagnosis of bovine udder infection and determination of milk quality* (p. 47). National Mastitis Council.

On-Nom, N., Grandison, A. S., & Lewis, M. J. (2010). Measurement of ionic calcium, pH, and soluble divalent cations in milk at high temperature. *Journal of Dairy Science*, *93*(2), 515–523. https://doi.org/10.3168/jds.2009-2634

Orregård, M. (2013). Quality analysis of raw milk along the value chain of the informal milk market in Kiambu County, Kenya. 4:1101–8151

Samia, M. A., Abd Elrahman, A. M. M., Said Ahmad, Ibtisam, E. M., El Zubeir, El Owani, O. A. O., & Ahmed, M. K., A. (2009). Microbiological and physicochemical properties of raw milk used for processing pasteurized milk in blue nile dairy …. *Australian Journal of Basic and Applied Sciences*, *3*(4), 3433–3437.

Tassew, A., & Seifu, E. (2011). Microbial quality of raw cow's milk collected from farmers and dairy cooperatives in Bahir Dar Zuria and Mecha district, Ethiopia. 29–33. https://doi.org/10.5251/abjna.2011.2.1.29.33

Te-Giffel, M. C. (2003). Good hygienic practice in milk processing. *Dairy Processing: improving Quality*, 68–80. https://doi.org/10.1533/9781855737075.