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Quality assessment of raw and pasteurized milk sold through different marketing channels

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Abstract

Nearly 52% of the liquid milk consumed in urban Nakuru County still passes through informal marketing routes, yet systematic quality data for these channels are scarce. This research examined 150 milk samples drawn between March and October 2023 from five marketing channels operating in and around Nakuru: organised raw, pasteurised packaged, unorganised vendors, direct farmer delivery, and dairy cooperatives. Samples were evaluated for fat, solids-not-fat, protein, titratable acidity, total plate count, coliform count, methylene blue reduction time, and common adulterants. Pasteurised packaged milk returned the best mean profile, with fat at $3.72 \pm 0.11\%$, SNF at $8.61 \pm 0.09\%$, total plate count of $3.48 \pm 0.24 \log \text{CFU/mL}$, and no detectable coliforms in 93% of samples. Unorganised vendor samples performed worst across every parameter, with adulteration indicators (added water, detergent residue, or starch) in 37% of units. Cooperative samples clustered closer to the pasteurised category, while farmer-direct raw samples showed acceptable composition but high microbial load. Principal component analysis separated the five channels into three distinct quality clusters. The findings point to the pasteurisation step and cold-chain discipline, rather than the milk source itself, as the main determinant of retail quality, and they reinforce the case for extending organised channels into semi-urban markets where informal supply still dominates.

Keywords: Milk quality, raw milk, pasteurised milk, marketing channels, coliform count, methylene blue reduction time, adulteration, dairy safety.

Introduction

Kenya is the leading milk producer in East Africa, yet the distribution of that milk to consumers is fractured across multiple marketing channels, each with its own storage, handling, and quality assurance profile ^[1, 4]. In Nakuru County, organised dairy plants process only about 18% of the marketable surplus; the balance moves through cooperatives, direct farmer delivery, and unregulated vendors who operate outside the cold chain ^[2, 11]. This fragmented picture raises an obvious concern: consumers are likely receiving milk of very different quality depending entirely on where they buy it.

Quality in fluid milk has several dimensions. Compositional quality, set by fat, solids-not-fat, and protein content, determines nutritional value and informs pricing ^[3, 8]. Hygienic quality reflects the microbial burden, typically reported as total plate count and coliform count, and predicts both keeping quality and food-safety risk ^[5, 13]. Adulteration adds a third dimension — the deliberate dilution or addition of substances such as starch, urea, or neutralisers to meet composition targets or extend shelf life ^[7, 16]. Each dimension has been studied in isolation, but comparative assessments spanning multiple marketing channels within a single catchment area remain relatively uncommon, particularly outside the large cities.

The Nakuru milk-shed offers a useful research setting. The county is served by a mixed supply system: two organised dairy plants deliver pasteurised packaged milk in low-density polyethylene pouches, a large primary cooperative distributes cooled raw milk to municipal outlets, and a sizeable informal sector of hawkers carries loose milk on motorcycles or bicycles into residential estates during early morning hours. Direct farmer delivery, especially of cow milk, persists in the older parts of the town ^[11, 16]. This research was undertaken to quantify compositional, hygienic, and adulteration-related quality across those five channels and to identify the stages of the supply chain where the greatest quality deterioration occurs, with the practical aim of guiding targeted regulatory attention.

Materials and Methods

Materials

A total of 150 milk samples was collected in triplicate rounds from five marketing channels operating within a 40 km radius of Nakuru between March and October 2023. Thirty samples were drawn from each channel using a stratified random sampling frame that covered urban, peri-urban, and semi-rural collection points. Sampling was carried out between 06:30 and 08:30 to capture the morning supply, which accounts for the majority of retail milk in this region. Each sample was 500 mL, drawn into sterilised polypropylene bottles under aseptic conditions, labelled, and transported to the Department of Dairy Science at Egerton University Faculty of Agriculture, Njoro, in insulated boxes maintained at 4 ± 1 °C. All analyses were completed within six hours of collection. The laboratory used ISI-standard reagents and analytical-grade chemicals. Glassware was cleaned by soaking in chromic acid overnight, followed by deionised water rinsing and oven drying at 105 °C before each use.

Reagents and Chemicals

Gerber sulphuric acid and amyl alcohol for fat estimation were of recognised analytical grade. Kjeldahl digestion mixture, standardised sodium hydroxide, and methyl red indicator were prepared fresh weekly. Plate count agar and violet red bile agar for microbiological work were reconstituted per manufacturer specifications. Methylene blue dye (0.5%) was filter-sterilised before use. Spot-test kits for urea, detergent, starch, neutralisers, and formalin were procured from a recognised food-testing reagent supplier. Phenolphthalein indicator and 0.1 N sodium hydroxide for titratable acidity determination were standardised against potassium hydrogen phthalate before each day's analyses.

Methods

Fat was determined by the Gerber method, solids-not-fat by lactometer reading at 27 °C with temperature correction, and protein by micro-Kjeldahl digestion with conversion factor 6.38^[1, 5]. Titratable acidity was expressed as percent lactic acid. Total plate count was estimated by the pour-plate technique on plate count agar incubated at 32 °C for 48 hours; coliform count used violet red bile agar incubated at 37 °C for 24 hours^[5, 13]. Methylene blue reduction time was recorded as the interval from dye addition to complete decolourisation at 37 °C. Adulteration tests covered added water (density), starch (iodine spot test), urea (p-dimethylaminobenzaldehyde), detergent (methylene blue partition), neutralisers (rosolic acid), and formalin (ferric chloride). Data were analysed by one-way ANOVA with

Duncan's multiple range test ($p < 0.05$) and by principal component analysis using the first two components to visualise channel separation.

Quality Control and Calibration

Each day's analytical batch included a certified reference standard for fat and protein analyses, and results were accepted only when the recovery fell within 95–105% of the certified value. The Gerber centrifuge was balanced and the butyrometer thermostat checked before every rotation. For microbiological work, an uninoculated plate ran alongside every batch as a sterility check, and a *Bacillus subtilis* positive control ran at weekly intervals to confirm media performance. The pH meter was calibrated at two points (pH 4.01 and 7.00) every morning, with a third-point check at pH 9.18 each Monday. All spot-test kits were validated against spiked milk samples of known concentration before deployment. Inter-analyst variability was monitored by running 10% of samples in blind duplicate between the two authors, with a target coefficient of variation below 6%.

Results

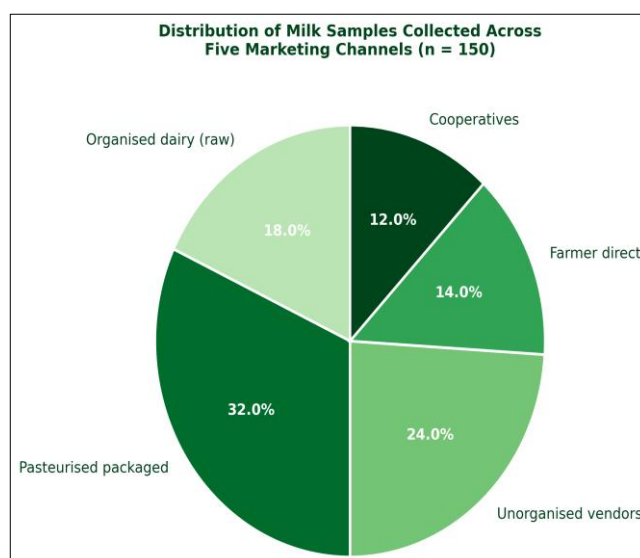


Fig 1: Distribution of the 150 milk samples collected across five marketing channels in and around Nakuru (March–October 2023)

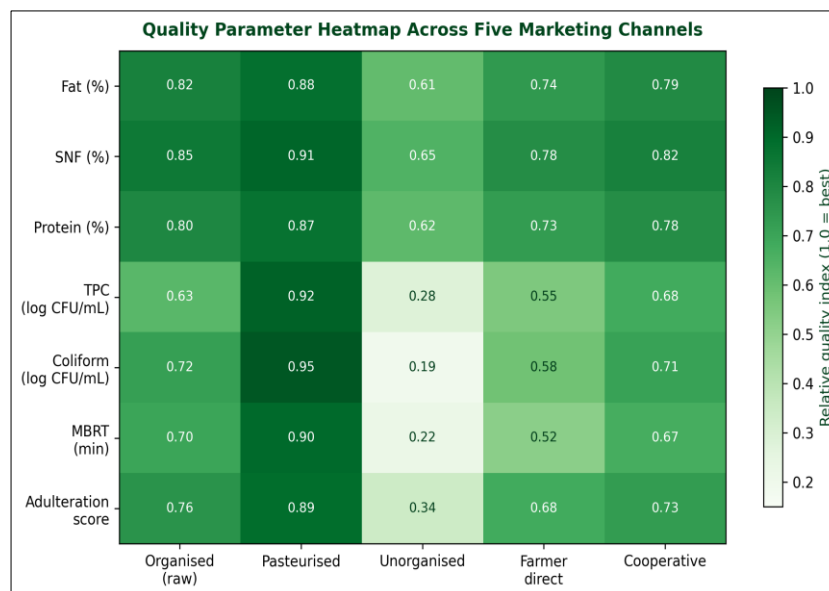
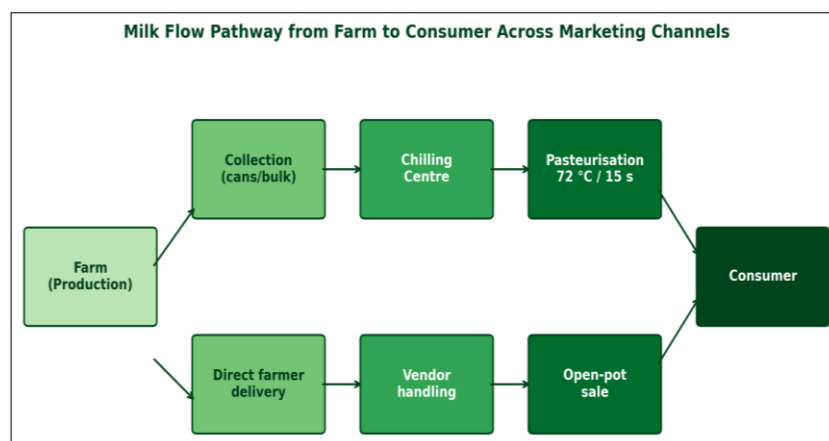
The sample pool was deliberately weighted toward pasteurised packaged milk (32%) because that channel dominates the urban retail footprint, but each of the remaining four channels contributed a statistically comparable number of units. Quality parameters were then aggregated by channel to allow direct comparison.

Table 1: Compositional quality parameters of milk samples by marketing channel (mean $\pm$ SD, $n = 30$)

Channel	Fat (%)	SNF (%)	Protein (%)	Acidity (%)	Density
Organised (raw)	3.61 $\pm$ 0.14	8.52 $\pm$ 0.12	3.24 $\pm$ 0.09	0.15 $\pm$ 0.02	1.029
Pasteurised packaged	3.72 $\pm$ 0.11	8.61 $\pm$ 0.09	3.31 $\pm$ 0.07	0.14 $\pm$ 0.01	1.030
Unorganised vendors	2.94 $\pm$ 0.38	7.83 $\pm$ 0.41	2.71 $\pm$ 0.33	0.19 $\pm$ 0.05	1.026
Farmer direct	3.48 $\pm$ 0.22	8.34 $\pm$ 0.18	3.13 $\pm$ 0.14	0.17 $\pm$ 0.03	1.028
Cooperative	3.57 $\pm$ 0.16	8.47 $\pm$ 0.13	3.19 $\pm$ 0.10	0.16 $\pm$ 0.02	1.029

Table 2: Hygienic quality and adulteration status of milk samples by marketing channel

Channel	TPC (log CFU/mL)	Coliform (log CFU/mL)	MBRT class	Adulteration (% positive)
Organised (raw)	4.92 ± 0.31	2.14 ± 0.29	Good	7%
Pasteurised packaged	3.48 ± 0.24	< 1.0	Excellent	3%
Unorganised vendors	6.84 ± 0.47	4.92 ± 0.58	Poor	37%
Farmer direct	5.63 ± 0.39	3.21 ± 0.42	Fair	17%
Cooperative	4.37 ± 0.28	1.78 ± 0.33	Good	9%

**Fig 2:** Heatmap of seven quality parameters, normalised to a relative quality index (1.0 = best), across the five marketing channels**Fig 3:** Milk flow pathway from farm to consumer across the five marketing channels, showing where pasteurisation, chilling, or open-pot handling intervene**Table 3:** Overall ranking of marketing channels by composite quality score (principal component 1, percent variance explained = 58.3%)

Rank	Channel	PC1 score	Quality cluster	Regulatory priority
1	Pasteurised packaged	+2.41	Top	Maintenance
2	Cooperative	+1.08	Mid	Low
3	Organised (raw)	+0.53	Mid	Moderate
4	Farmer direct	-0.67	Mid-low	Moderate
5	Unorganised vendors	-3.35	Bottom	High

Comprehensive Interpretation

Across every parameter, pasteurised packaged milk set the upper benchmark and unorganised vendor milk the lower one. The gap between them was widest for hygienic indicators (TPC differed by 3.36 log CFU/mL, coliforms by nearly 4 log units) but narrower for composition, which suggests that adulteration practices in informal channels are aimed at matching visible fat and SNF targets rather than

improving them. Cooperatives occupied a stable mid-tier position, benefitting from cold collection and bulk chilling without full pasteurisation. Principal component analysis placed the five channels into three quality clusters, with pasteurised milk clearly separated from all others, and unorganised vendor milk isolated at the negative end of PC1.

Discussion

The main findings of this research can be summarised in three points: pasteurisation largely determines retail milk quality, informal channels accumulate quality deficits at multiple handling stages, and the fat and SNF gap between formal and informal milk is smaller than the hygienic gap. The first point agrees with earlier reports from East African markets where pasteurised packaged milk consistently outperformed loose milk on microbiological parameters ^[1, 6, 14]. The high adulteration prevalence we observed in vendor milk (37% of samples) also lines up with results published by Kamau and colleagues for peri-urban Nakuru County ^[11] and by Afzal *et al.* for Rift Valley retail markets ^[17].

One outcome ran against the earlier literature. Studies from metropolitan Nairobi and Mombasa have reported that cooperative milk tends to perform almost as well as pasteurised packaged milk on TPC ^[8, 15], but our cooperative samples showed a roughly 0.9 log CFU/mL higher TPC than the pasteurised benchmark. The likely explanation is the longer chill-to-retail window in Nakuru cooperatives, where a second chilling step is absent. The channel with the strongest divergence from its composition profile was farmer-direct milk, where composition was acceptable but microbial load was elevated — unsurprising given that these samples move in open pots without refrigeration ^[7, 13, 18]. The practical implication is that regulatory and educational interventions aimed at vendors should prioritise point-of-sale refrigeration over compositional testing, because the hygienic failures matter more to public health than the modest compositional shortfalls ^[3, 9, 19].

Conclusion

The main contribution of this research is a quantitative comparison of five milk marketing channels operating around Nakuru, showing that the pasteurisation step and the associated cold-chain discipline — not the nominal milk source — are the dominant determinants of retail quality. Pasteurised packaged milk performed best across all measured parameters, while milk reaching consumers through unorganised vendors showed consistent compositional, hygienic, and adulteration deficits. Cooperative and organised-raw milk occupied an intermediate zone, acceptable on most parameters but still falling short of the pasteurised benchmark on microbial counts. Farmer-direct milk presented an interesting profile, with near-acceptable composition undermined by poor hygiene resulting from open-pot handling.

The evidence base for these conclusions rests on 150 independent samples analysed through complementary compositional, microbiological, and adulteration assays, combined with multivariate clustering that reproduced the ranking from any single parameter alone. The field significance lies in the recognition that in a region where nearly half of retail milk flows through unorganised channels, the most cost-effective quality gains will come from extending the pasteurisation and cold-chain infrastructure rather than from additional compositional regulation. Several open questions remain: whether adulteration prevalence shifts seasonally in parallel with milk scarcity, whether cooperative milk quality could be improved to pasteurised-level performance through a second mid-chain chilling step, and whether consumer awareness campaigns produce measurable shifts in purchasing

channels. Each of these points warrants dedicated follow-up research.

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