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Assessment of Physicochemical, Sensory and Microbiological Quality of Raw Milk and Reconstituted Milk as Feedstock for Dairy Units in Dori, Burkina Faso

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A B S T R A C T

This study aimed to assess the physicochemical, sensory, and hygienic quality of milk destined for dairy processing units in Dori. Raw milk (n=10) derived from 10 farm-milking cows. Reconstituted milk (n=10) was powder milk added with water at 1/5, 1/7, 1/8, and 1/10 (kg/L), respectively. Physicochemical and microbiological parameters and sensory perception were analyzed. Results showed pH was unsuitable in raw milk (6.30) and reconstituted milk (6.28). The acidity (16.90°D), density (1.032), non-fat dry matter (9.34%), fat (3.91%), lactose (5.13%), and protein (3.42%) contents were by standards in 90-100% of raw milk against 7.5-20% of reconstituted milk. Raw milk was more satisfactory sensory quality than reconstituted milk. However, 90-100% of raw milk was poor sanitary quality regarding total aerobic mesophilic flora, negative-coagulase staphylococci, yeasts and molds ($4.35x10^6$, $1.12x10^6$ and $1.48x10^3$ CFU/mL, respectively), whereas 70-100% was acceptable quality to total and fecal coliforms ($1.25x10^3$and $6.84x10^2$ CFU/mL, respectively). Conversely, 100% of reconstituted milk was poor quality regarding total and fecal coliforms ($3.88x10^4$, $4.39x10^3$ CFU/g, respectively). These analyses highlight potentially hazardous products that can pose a serious public health risk and spoil the quality of end-products of dairy units if the milk is not adequately processed and highly adulterated by adding water.

Keywords

Raw cow milk, reconstituted milk, physicochemical properties, sensory perception, sanitary quality, milk adulteration

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Introduction

Milk is a food that has continued to deserve huge attention worldwide for several decades. Its richness and abundance in protein, fat, carbohydrates, vitamins, microelements, hormones, enzymes, as well as other molecules and minerals confer antimicrobial, antidiabetic, anticarcinogenic, and antiobesity properties to milk (Armas *et al.,* 2016; Park *et al.,* 2013). That denotes milk's importance in human and animal nutrition and the fact that it is considered a complete diet than other foods. World raw milk production is increasing and surpassed 843 million tons in 2018 to reach 935.9 million tons in 2022 (Dairy News, 2023; FAO, 2023).

In Africa, its production is growing slowly owing to climate conditions, low pasture management, and limited financial resources in several developing countries where livestock production is widely based on traditional extensive systems. More than 80% of the milk produced in sub-Saharan Africa comes from small-scale dairy producers (Nyameasem *et al.,* 2018).

In Burkina Faso, milk production has been steadily increasing over the last two decades and was estimated at 264 million liters per year in 2019 (FAO, 2019). Only 2-4 million liters of raw milk are delivered to dairies and the remainder to consumers and producers (GIZ, 2018). However, milk demand is increasingly growing because of its use in processing and obtaining various typical dairy end-products (yogurt, cheese, butter), local fermented products (Gapal, curdled milk, dèguè), and butter oil-based traditional soap. Despite the potential of the Sahelian regions of Burkina Faso in livestock and raw milk production, the country imports powder milk for the equivalent of 70 million liters of fluid milk to make up for deficits due to the growing demand in urban centers and dairy units (GIZ, 2018). During the 9-month dry season, raw cow milk becomes scarce and expensive. Hence, imported powder milk is used for routine dairy runs on the one hand, and breeders and collectors are prone to milk adulteration by adding water and/or starch into milk for enhancing financial benefits on the other hand during this lean period.

Adulteration of milk can modify and alter the intrinsic quality of milk and consequently dairy products. It is reported that there exists a relationship between some physicochemical parameters of milk. Thus, valuable outcomes from the subject parameters analyzed can provide the quality of milk and suspicion of adulteration (Baran and Adigüzel, 2020). Most dairies are mainly small- (mini dairies) and family-scale. They are sometimes under-equipped to determine the quality of milk reconstituted by themselves or supplied by farmers and collectors. Also, the adulteration of milk can constitute a source of microbial contamination via water and/or ingredients. The knowledge of quality parameters (physiochemistry, nutrition, microbiology) of milk remains very poor among milkers, collectors, and dairy workers who are most illiterate people. Yet the sensory perception approach could be readily used to approximatively differentiate right milk from wrong/reconstituted milk by checking the subject physicochemical parameters.

To address this approach, the raw milk freshly milked from cows serves as a control to determine the quality parameters of milk in comparison with reconstituted milk deriving from water addition in the present study. Thus, this study aimed to ascertain the physicochemical, sensory, and microbial parameters of raw milk and reconstituted milk. The relationship between physicochemical parameters and sensory perception of panelists as well as the milk quality regarding physicochemical and microbiological characteristics were discussed according to recognized standards.

Materials and Methods

Milk sampling

Samples originated from a cattle farm in the city of Dori, north of Burkina Faso, West Africa. From the milking routine combined both the stimulation of cow teats by calf and suckling, 10 raw milk samples were drawn from 10 calf-suckling cows by the same milker using a hand-milking technique as described elsewhere (Millogo *et al.*, 2010). About 500 mL of samples were transferred into sterile air-free 500 mL bottles and kept in an icebox with ice blocks during field sampling. Then, samples were transported to the Pamira Omborine dairy unit located in Dori for the physicochemical and sensorial analyses within 1-2 hours after sampling. As for the microbial load in milk, the samples were stored at 4°C and transported to the laboratory of Département Technologie Alimentaire (DTA/IRSAT/CNRST) in Ouagadougou for microbiological analysis. Besides, industrial powder milk samples (1 kg) were purchased and kept dry in their packaging from 4 different retailers in Dori for the analyses mentioned above.

Physicochemical analysis

The pH, density, fat, non-fat dry matter, lactose, and protein contents were measured using the equipment Lactoscan SP according to the manufacturer's instructions. The total dry matter content was determined by the addition of fat content and non-fat dry matter (Baran and Adigüzel, 2020). The raw milk samples were directly used for analysis while the reconstituted milk samples were prepared from powder milk stock following four different ranges according to the adapted VITALREST (2017) protocol as shown in Table 1.

Table.1 Composition of different types of reconstituted milk

Type No.	Standard composition (powder milk weight + water volume)	Lab-working composition (powder milk weight + water volume)
Type 1	1 Kg + 5 L	50 g + 250 mL
Type 2	1 Kg + 7 L	50 g + 350 mL
Type 3	1 Kg + 8 L	50 g + 400 mL
Type 4	1 Kg + 10 L	50 g + 500 mL

A 20 mL volume of each milk sample was withdrawn and analyzed using an aspirator device to determine the required parameters simultaneously.

The Dornic acidity (°D) of milk samples (10 mL) was determined by titration using NaOH (N/9) according to the standard method (AOAC, 2012).

Sensory perception

The organoleptic quality of raw milk and reconstituted milk was determined based on consumer perception. Thus, a survey was performed next to 15 volunteer respondents randomly selected in the dairy unit and surroundings. The concerned parameters were namely, taste, odor, color, viscosity, and homogeneity of milk samples.

Microbiological analysis

The microbiological analyses of milk samples were carried out according to the standard techniques of microbiological analysis. Ten grams of powder milk samples and 10 mL of raw milk samples were individually mixed in 90 mL of sterile physiological saline solution (0.9% NaCl, w/v) contained in a sterile stomacher bag. The mixtures were thoroughly vortexed at normal speed for 2 minutes. The suspensions were serially diluted 10-fold up to 10^{-4} or 10^{-7} regarding the targeted germ. One mL of each dilution was poured on different agar media plates for microbial growth.

All microbial cultures were performed as described by Compaoré *et al.*, (2021). Total Aerobic Mesophilic Flora (TAMF) was enumerated on the Plate Count Agar (PCA) medium incubated at 30°C for 72 hours according to ISO 4833 (2003). Yeasts and molds were enumerated on Sabouraud CAF with chloramphenicol agar plates incubated at 25°C for 3-5 days according to ISO 7402 (1993). Total coliforms and fecal coliforms were enumerated on Violet Red Bile Lactose (VRBL) agar plates incubated for 24-48 hours at 37°C and 44°C, respectively, according to ISO 7402 (1993).

Staphylococci were enumerated on Baird-Barker agar plates incubated at 37°C for 24 hours according to ISO 6888-1 (1993). The search of hemolytic staphylococci, in particular *Staphylococcus aureus*, was performed across the coagulase test by cultivating 0.5 mL staphylococci-suspension with 0.5 mL rehydrated plasma at 37°C for 4 hours. All experiments were carried out in duplicate and sterile conditions.

After the incubation duration of each corresponding target germ, the number of characteristic colonies comprised between 30-300 colony-forming units (CFU) was considered for the TAMF count, while 15-150 CFU for total coliforms, fecal coliforms, staphylococci, and yeasts and molds counts. Results were expressed as CFU/mL and CFU/g for raw milk and powder milk samples, respectively.

Data Processing

Values were expressed as mean ± standard deviation (SD) of different analyses of each sample. The data were statistically analyzed using the statistical software StatPlus:mac, and graphs were drawn by Microsoft Excel software. The significant differences between means for each analyzed parameter between raw milk and reconstituted/powder milk were calculated by a one-way analysis of variance (ANOVA) using the Tukey HSD test at threshold $P < 0.05$. The Pearson's correlation test was carried out to check the interdependence between parameters, and then the relationship between the dilution of reconstituted milk and different parameters at the significant threshold $P < 0.05$.

Results and Discussion

Physicochemical characteristics of milk

The pH, density, and content of dry matter, fat, lactose, and protein were not detected in 1kg/5L- and 1kg/7L-reconstituted milk samples by the device LACTOSCAN used in the present experiment. This was due to their high concentration which prevented the device measurement with regards to the detection threshold of the device for each other parameters. However, these physicochemical parameters have been measured in raw milk and 1kg/8L- and 1kg/10L-reconstituted milk samples as summarized in graphs (Fig. 1).

The average pH was 6.30 ± 0.02, 6.26 ± 0.06, and 6.30 ± 0.06 in raw milk, 1kg/8L- and 1kg/10L-reconstituted milk, respectively. No significant difference ($P = 0.245$) was noted for the pH value whatever the type of milk (raw and reconstituted) (Fig. 1a, Table 2).

The Dornic acidity of the raw milk ranged from 16-18°D with a mean value of 16.90 ± 0.83°D (Fig. 1b, Table 2). In the reconstituted milk, the average acidity was 21.40 ± 6.51, 13.90 ± 1.37, 11.90 ± 1.45, and 8.80 ± 0.98°D for 1kg/5L, 1kg/7L, 1kg/8L and 1kg/10L samples, respectively. The average value of acidity of all reconstituted milk samples was 14.00 ± 5.78°D (Table 2). The acidity was significantly different between raw milk and overall reconstituted milk ($P< 0.001$), except with 1kg/7L reconstituted milk ($P = 0.259$) (Fig.1b).

A density of 1.032 ± 0.001, 1.030 ± 0.006, and 1.026 ± 0.002 was measured in raw milk, 1kg/8L- and 1kg/10L-reconstituted milk, respectively (Fig. 1c, Table 2). The raw milk had a density significantly higher than that of 1kg/10L-reconstituted milk ($P = 0.002$), but slightly similar to that of 1kg/8L-reconstituted milk ($P = 0.527$). Nevertheless, the density of raw milk was significantly higher than that of reconstituted milk samples (1.028 ± 0.005; $P= 0.017$) overall in this study (Table 2).

As for the non-fat dry matter (NFDM) content, the raw milk recorded a higher amount (9.34 ± 0.16%) compared with that of 1kg/8L milk (9.06 ± 1.79%, $P = 0.588$) and 1kg/10L milk (7.36 ± 0.63%, $P< 0.001$) (Fig. 1d). It was noted a dry matter content significantly greater in raw milk in comparison with reconstituted milk samples (8.21 ± 1.56%, $P = 0.038$) (Table 2).

The tendency with total dry matter content is similar to NFDM where a higher mean value (13.25 ± 0.19 %) was found in raw milk than in reconstituted milk at 1kg/8L (13.72 ± 3.13%, *P* = 0.865) and 1kg/10L milk samples (9.82 ± 1.07%, *P*= 0.002) (Fig. 1e, Table 2).

The biochemical compounds in experimented milk samples revealed a variation in the fat, lactose, and protein contents. Indeed, the fat content was 3.91 ± 0.23, 4.66 ± 1.50, and 2.46 ± 0.49% in raw milk, 1kg/8L- and 1kg/10L-reconstituted milk, respectively (Fig. 1f).

Although the fat content in raw milk is intermediate to that of individually reconstituted milk samples, it was significantly higher in raw milk than in 1kg/10L-reconstituted milk (*P* = 0.007) but lower in 1kg/18L-reconstituted milk (*P* = 0.217) (Fig. 1f). As pH, there is no significant difference of fat content between the raw milk and the whole reconstituted milk (3.56 ± 1.57%, *P* = 0.499) as shown in Table 2.

The lactose content was higher in raw milk (5.13 ± 0.09%) compared with 1kg/8L-reconstituted milk (4.97 ± 0.98%, *P* = 0.839) and 1kg/10L-reconstituted milk (4.03 ± 0.32%, *P* = 0.002) respectively (Fig. 1g). Hereby, the raw milk presented the highest value of lactose content face to whole reconstituted milk samples (4.50 ± 0.86%, *P* = 0.035) (Table 2).

The protein content had the same trend as the lactose one. The raw milk had the highest protein content (3.42 ± 0.06%) followed by 1kg/8L-reconstituted milk (3.31 ± 0.65%, *P* = 0.840) and 1kg/10L-reconstituted milk (2.69 ± 0.21%, *P* = 0.002) (Fig. 1h). The protein content was significantly higher in raw milk than all reconstituted milk samples (3.00 ± 0.58%, *P* = 0.036) (Table 2).

Relationships between the physicochemical parameters of raw and reconstituted milk

On an overview, the physicochemical parameters of reconstituted milk samples namely, acidity, density, dry matter, fat, lactose, and protein had a potent positive relationship with each other, except for pH where no correlation was noted with other parameters (*P*> 0.05) (Table 3). It was observed that the increase of each physicochemical parameter value led to enhancing strongly and positively other parameters in reconstituted milk (0.510-1; *P*< 0.05-0.001) (Table 3).

In raw milk, the trend of pH relationship with other parameters was similar to reconstituted milk one's, in addition to acidity where no correlation was noted with other parameters (-0.141 to 0.269; *P*> 0.05) (Table 3). However, the fat content was negatively correlated to density, NFDM, lactose, and protein (*P*< 0.05), whereas a positive close correlation was exclusively noted between the density, NFDM, lactose, and protein (0.907-0.999, *P*< 0.001) in raw milk (Table 3). The TDM content in raw milk was strongly related to fat content and pH value (0.753 and 0.576, respectively, *P*< 0.05), but without any link with other physicochemical parameters (*P*> 0.05) (Table 3).

Effect of adulteration of milk on physicochemical parameters

Inversely to the tendency observed in the high correlation between most of the physicochemical parameters of reconstituted milk samples, it is germane to note here that the increasing of water addition into reconstituted milk had a negative intermediate relationship, although not significant (*P*>0.05). This led to a drop in overall physicochemical values as readily observed in Fig. 1 and settled in Table 4. This means that the more the reconstituted milk was diluted, the lower the physicochemical values. On the other hand, increasing the adulteration of milk with water led to a high increase in the pH of reconstituted milk (R = 0.795; *P* = 0.003) as shown in Fig. 1 and Table 4.

Sensory quality of milk

The survey based on the organoleptic characteristics of raw milk and reconstituted milk samples perceived by the respondents is depicted in Fig. 2. In this study, the panelists (%) found that the raw milk had the following features: light-yellow color (67.7%), sweet taste (80.0%), more and less particular smell (46.7-53.3%), no viscosity (100%), and better homogeneity (100%).

Microbiological quality of milk

Overall, the microbial analysis showed that the averages of total aerobic mesophilic flora (TAMF), staphylococci, and yeasts and molds counts were significantly 100-, 100,000- and 100-fold higher in raw milk freshly collected from cows on the farm than in powder milk samples collected from retail ($P< 0.05$). Conversely, the powder milk samples were significantly 10-fold more loaded as regards the total coliforms and fecal coliforms than in the raw milk ($P< 0.05$).

TAMF varied from $1.15x10^6$-$9.32x10^6$ CFU/mL and $1.09x10^4$-$9.09x10^4$ CFU/g in raw milk and powder milk, respectively. The mean TAMF count was significantly greater in raw milk ($4.35x10^6$ CFU/mL, 6.48 log CFU/mL) than in powder milk ($4.11x10^4$ CFU/g, 4.49 log CFU/g) ($P = 0.004$) (Table 5, Fig. 3).

Staphylococci count ranged from $4.59x10^5$-$2.50x10^6$ CFU/mL and less than 10 CFU/g in raw milk and powder milk, respectively. These bacteria were highly encountered in raw milk ($1.12x10^6$ CFU/mL, 5.97 log CFU/mL) in comparison with powder milk (<10 CFU/g, <1.0 log CFU/g) ($P< 0.001$) (Table 5, Fig.3).

Yeasts and molds showed a variation of $2.68x10^2$-$3.23x10^3$ CFU/mL in raw milk whereas they were less than 10 CFU/g in powder milk. Yeasts and molds were significantly more predominant in raw milk ($1.48x10^3$ CFU/mL, 2.98 log CFU/mL) than in powder milk (<10 CFU/g; <1.0 log CFU/g) ($P = 0.009$) (Table 5, Fig.3).

As for total coliforms, the ranges of $8.82x10^1$-$3.45x10^3$ CFU/mL and $5.86x10^3$-$9.82x10^4$ CFU/g were recorded in raw milk and powder milk, respectively. Fecal coliforms accounted for $8.45x10^1$-$9.09x10^2$ CFU/mL and $1.09x10^3$-$7.27x10^3$ CFU/g in raw milk and powder milk, respectively. In general, both total and fecal coliforms count was rather of an order of magnitude 10-fold lower in raw cow milk than in powder milk samples ($P< 0.05$) (Table 5, Fig. 3).

The means of total coliforms and fecal coliforms were on the order of $1.25x10^3$ CFU/mL (2.91 log CFU/mL) and $6.84x10^2$ CFU/mL (2.77 log CFU/mL) in raw milk, respectively. Whereas in powder milk, the averages of total coliforms and fecal coliforms were $3.88x10^4$ CFU/g (4.34 log CFU/g) and $4.39x10^3$ CFU/g (3.56 log CFU/g), respectively.

Physicochemical quality

In this study, it is germane to indicate here that all raw cow milk samples (100%) complied with the standards of studied physical and chemical parameters settled in Table 2, except the pH. Conversely, overall reconstituted milk samples did not respect the threshold of these parameters.

This demonstrates that fresh raw cow milk saves perfectly the physicochemical properties than reconstituted milk, and consequently is a better feedstock for dairy units and consumers. The adulteration of milk with water highlights that the reconstituted milk loses its physicochemical characteristics by decreasing values as shown throughout the positive correlation but not significant.

The density (or specific gravity) of liquid milk is one of the main indications of adulteration suspicious by adding water (intentionally or accidentally) with values below 1.026 (EAC, 2006), whereas higher values (≥1.035) indicate skimming off fat (O' Conner, 1993).

The present study outcomes revealed that 50, 35 and 15% of reconstituted milk samples were below, normal, and above these limits, respectively. Several studies found the density values of raw milk more and less similar to this study ranging from 1.029-1.071 (Assouhoun-Djeni *et al.,* 2020), 1.022-1.032 (Gemechu and Amene, 2016; Sissao *et al.*, 2015; Swai and Schoonman, 2011).

The pH and acidity are both important parameters to determine quickly the milk quality in dairy farms and units. These parameters provide information about milk purity, deterioration, mastitis infection symptoms, and total acid concentration due to microbial activity in milk. Overall, the pH of both milk samples was not within the pH standard value, while 100 and 7.50% of raw milk and reconstituted milk complied with the acidity standard, respectively. There is well-known a negative correlation between pH and acidity (Fava *et al.,* 2014; Gemechu and Amene, 2016) as observed in present study reconstituted milk samples but contrary in raw milk. The suitable value of acidity in present study raw milk samples denotes weak lactic acid production by lactic bacteria, although these bacteria have not been enumerated in this experiment.

In elsewhere studies, pH values were notified in raw milk derived from farms and collect centers in Burkina Faso around 6.62-6.72 (Kazienga *et al.,* 2016), 6.6 (Millogo *et al.*, 2018), 6.41-6.49 (Sissao *et al.*, 2015), 5.9-6.5 in Côte d'Ivoire (Assouhoun-Djeni *et al.,* 2020), and 6.15-6.64 in Ethiopia (Gemechu and Amene, 2016). The pH of powder milk (6.30-6.45) found by Gorga *et al.,* (2021) was close to that of present study reconstituted milk samples.

Based on 1°D equals 0.1 g lactic acid/liter (0.01%), the acidity values found in present study experiment with raw milk were similar to those of Gemechu and Amene (2016) (17.4-21.5°D) but lower than those of Assouhoun-Djeni *et al.,* (2020) (17-36°D). The fat, lactose, and protein contents were satisfactory in all raw milk (100%), while in reconstituted milk they were 10, 20 and 15% satisfactory with regard to standards, respectively.

Several studies were carried out on the chemical composition of raw milk in the main cities and peri-urban areas in Burkina Faso. Hence, the fat content recorded in raw milk collected from farms ranged from 3.71, 3.85-5.1, 2.3-3.9 and 3.24-5.99% as reported by Compaoré *et al.,* (2021); Kazienga *et al.,* (2016); Millogo *et al.,* (2018) and Sissao *et al.,* (2015), respectively. These authors found the content of lactose ranging from 4.76-4.91 (Kazienga *et al.,* 2016), 5.1-5.2 Millogo *et al.,* (2018), 4.12-4.32% (Sissao *et al.*, 2015). As for protein content, they revealed value variations of 1.69 (Compaoré *et al.*, 2021), 3.40-3.43 (Kazienga *et al.*, 2016), 3.7-3.8 Millogo *et al.,* (2018), 2.89-3.77% (Sissao *et al.,* 2015) in raw milk taken from farms. The present study findings related to these chemical compounds were within those of these authors.

The total dry matter content of milk depends on its chemical components (lactose, protein, and fat) contents. The total dry matter content increases with increasing of lactose, protein, and fat in reconstituted milk as well as in raw milk, as mentioned above in the correlation analysis. This finding is in accordance with Millogo *et al.*, (2018) and Baran and Adigüzel (2020) studies. Most of the present study raw milk (90%) presented compliance with the non-fat dry matter standard comparatively to reconstituted milk samples (15%), while the total dry matter content in raw milk (13.25 ± 0.19%) was slightly higher than the standard limit and higher than in reconstituted milk. The present study values are included within those found by Kazienga *et al.*, (2016) (13.13-13.69%), Millogo *et al.*, (2018) (12.1-14%), Sissao *et al.,* (2015) (11.74-14.82%) in Burkina Faso, Asefa and Teshome (2019) (11.08-13.40%) in Ethiopia, and similar to that of Ekpa and Onuh (2018) (13.26%) in Nigeria.

It is well-known that the physical properties and content of chemical compounds of raw milk can be influenced by several factors namely, the breed, feed, age, and health state status of milking cows, season and interval of milking, technical completeness of milking, stage of lactation milking and milker skills, as reported by O'Connor (1995). Also, microbial activities such as the degradation of lactose, proteins, and lipids in milk can modify milk composition (O'Connor, 1995).

Table.2 Physicochemical properties of raw milk and reconstituted milk samples

	Raw milk	Reconstituted milk					Standard values
		1kg/5L	1kg/7L	1kg/8L	1kg/10L	Overall means	
pH	6.30 ± 0.02[a] (6.27-6.33)	nd	nd	6.26 ± 0.06[a] (6.12-6.35)	6.30 ± 0.06[a] (6.16-6.35)	6.28 ± 0.06[a]	6.6–6.8*
Acidity (°D)	16.90 ± 0.83[a] (16-18)	21.40 ± 6.51[b] (16-40)	13.90 ± 1.37[ac] (13-17)	11.90 ± 1.45[cd] (10-14)	8.80 ± 0.98[de] (7-10)	14.00 ± 5.78[b]	15–17* 16-18**
Density	1.032 ± 0.001[a] (1.031-1.033)	nd	nd	1.030 ± 0.006[a] (1.017-1.036)	1.026 ± 0.002[b] (1.023-1.030)	1.028 ± 0.005[b]	1.028–1.033*
NFDM (%)	9.34 ± 0.16[a] (9.08-9.60)	nd	nd	9.06 ± 1.79 [a] (5.33-11.11)	7.36 ± 0.63[b] (6.58-8.89)	8.21 ± 1.56[b]	9–9.5*
TDM (%)	13.25 ± 0.19[a] (13.22-13.67)	nd	nd	13.72 ± 3.13[a] (8.67-17.65)	9.82 ± 1.07[b] (8.58-12.67)	11.77 ± 3.04[b]	12.5–13.0*
Fat (%)	3.91 ± 0.23[a] (3.68-4.50)	nd	nd	4.66 ± 1.50[a] (2.00-6.23)	2.46 ± 0.49[b] (1.19-3.78)	3.56 ± 1.57[a]	3.5–4.5*
Lactose (%)	5.13 ± 0.09[a] (4.98-5.27)	nd	nd	4.97 ± 0.98[a] (2.92-6.09)	4.03 ± 0.32[b] (3.61-4.77)	4.50 ± 0.86[b]	4.7–5.2*
Protein (%)	3.42 ± 0.06[a] (3.32-3.52)	nd	nd	3.31 ± 0.65[a] (1.94-4.06)	2.69 ± 0.21[b] (2.41-3.18)	3.00 ± 0.58[b]	3.3–3.6*

Means (n = 10) ± SD in a line with the different superscript letters are significantly different at $P< 0.05$ between raw milk and each reconstituted milk on the one hand, and between raw milk and overall reconstituted milk on the other hand; Values in brackets indicate the value intervals of 10 samples for each parameter; nd: not determined; NFDM: Non-fat dry matter; TDM: Total dry matter; *: FAO (1985, 1995); **: Code Alimentarius (2011).

Table.3 Correlation of physicochemical parameters inraw milk and reconstituted milk.

	pH	Density	Fat	NFDM	TDM	Lactose	Protein	Acidity
pH	1	0.000 (*P*=0.5)	0.284 (*P*=0.213)	0.271 (*P*=0.224)	0.576 (*P*=0.041)	0.278 (*P*=0.218)	0.275 (*P*=0.221)	0.269 (*P*=0.226)
Density	- 0.295 (*P*=0.104)	1	- 0.821 (*P*=0.002)	0.907 (*P*<0.001)	- 0.276 (*P*=0.220)	0.911 (*P*<0.001)	0.920 (*P*<0.001)	0.000 (*P*=0.5)
Fat	- 0.361 (*P*=0.059)	0.774 (*P*<0.001)	1	- 0.598 (*P*=0.034)	0.753 (*P*=0.006)	- 0.599 (*P*=0.034)	- 0.623 (*P*=0.027)	- 0.141 (*P*=0.348)
NFDM	- 0.319 (*P*=0.085)	0.988 (*P*<0.001)	0.859 (*P*<0.001)	1	0.077 (*P*=0.416)	0.999 (*P*=0.000)	0.998 (*P*=0.000)	0.201 (*P*=0.289)
TDM	- 0.352 (*P*=0.064)	0.914 (*P*<0.001)	0.964 (*P*<0.001)	0.964 (*P*<0.001)	1	0.076 (*P*=0.417)	0.045 (*P*=0.451)	- 0.011 (*P*=0.488)
Lactose	- 0.320 (*P*=0.085)	0.988 (*P*<0.001)	0.858 (*P*<0.001)	1 (*P*<0.001)	0.964 (*P*<0.001)	1	0.998 (*P*=0.000)	0.187 (*P*=0.302)
Protein	- 0.317 (*P*=0.086	0.988 (*P*<0.001)	0.858 (*P*<0.001)	1 (*P*<0.001)	0.964 (*P*<0.001)	1 (*P*<0.001)	1	0.202 (*P*=0.288)
Acidity	- 0.351 (*P*=0.065)	0.510 (*P*=0.011)	0.617 (*P*=0.002)	0.559 (*P*=0.005)	0.610 (*P*=0.002)	0.563 (*P*=0.005)	0.564 (*P*=0.005)	1

Correlation values in raw milk and reconstituted milk are shown at the upper right and lower left of the diagonal, respectively. *P*: P values are significantly different at *P*<0.05.

Table.4 Correlation between physicochemical parameters and reconstituted milk.

Milk dilution rate	pH	Acidity	Density	NFDM	TDM	Fat	Lactose	Protein
1kg/8L *vs* 1kg/10L	0.795 (*P*=0.003)	- 0.367 (*P*=0.148)	- 0.490 (*P*=0.075)	- 0.460 (*P*=0.091)	- 0.435 (*P*=0.104)	- 0.399 (*P*=0.127)	- 0.428 (*P*=0.109)	- 0.429 (*P*=0.108)

P: P values for the significant difference at *P*<0.05.

Fig.1 Physicochemical parameters of raw milk and reconstituted milk samples at different dilutions (1kg/5L, 1kg/7L, 1kg/8L, 1kg/10L).

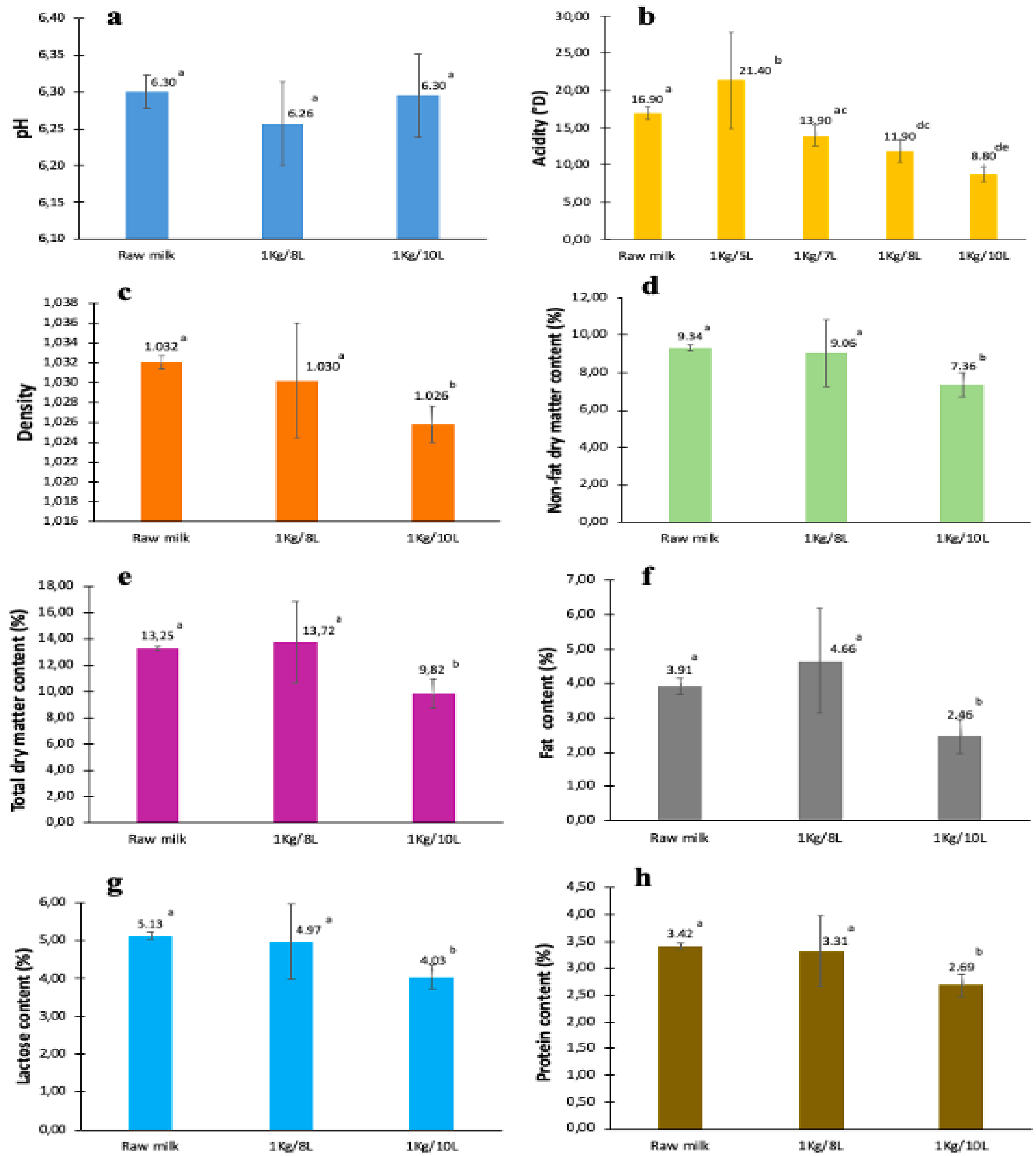


Table.5 Microbial cell count from raw milk and powder milk samples.

Samples	TAMF	Total coliforms	Fecal coliforms	Staphylococci	Yeasts + molds
Raw milk (CFU/mL)	$4.35x10^{6\ a}$ ± $3.18x10^{6}$	$1.25x10^{3a}$ ± $1.17x10^{3}$	$6.84x10^{2a}$ ± $2.32x10^{2}$	$1.12x10^{6a}$ ± $6.79x10^{5}$	$1.48x10^{3a}$ ± $1.26x10^{3}$
Powder milk (CFU/g)	$4.11x10^{4b}$ ± $2.86x10^{4}$	$3.88x10^{4\ b}$ ± $3.67x10^{4}$	$4.39x10^{3b}$ ± $2.12x10^{3}$	$<10^{b}$	$<10^{b}$
***P* values**	0.004	0.011	< 0.001	< 0.001	0.009

Means (n = 10) ± SD in a column with the different superscript letters are significantly different at $P< 0.05$

Fig.2 Perception of the organoleptic quality of raw milk and reconstituted milk by respondents.

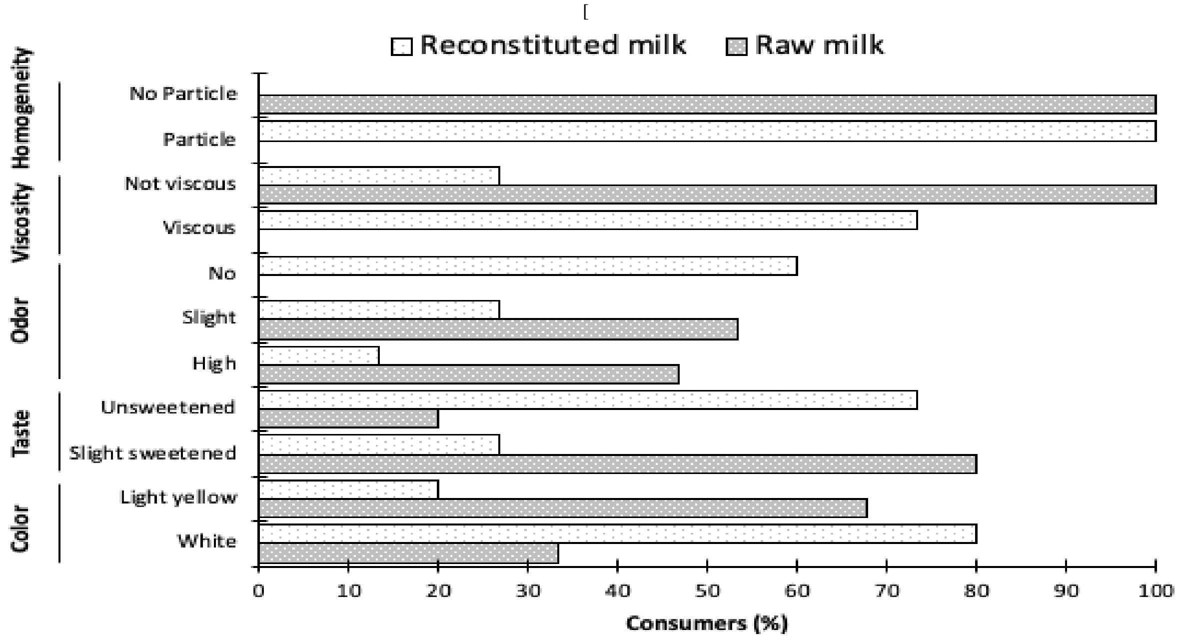
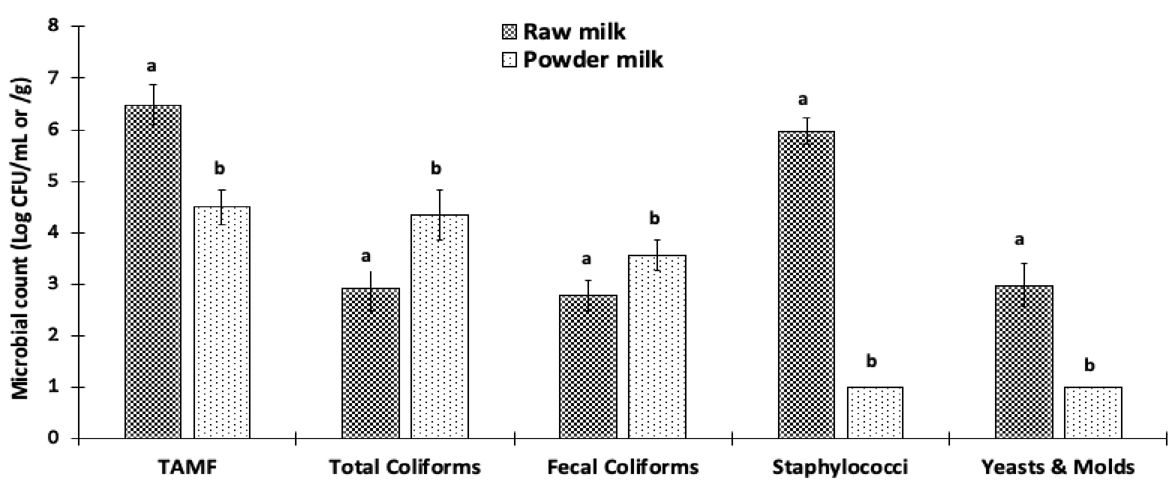


Fig.3 Logarithmic microbial load of raw milk and powder milk.



Sensory quality

In this study, the respondents expressed a positive appreciation toward the sensory features of raw milk than those of reconstituted milk. Indeed, the better organoleptic properties of raw milk originating from cows are well-recognized by its light-yellow color, slightly sweet taste, particularly pleasant smell, and absence of particles corroborating with its fluidity.

The variation of physicochemical features of milk can affect the sensory parameters of milk which can be precepted by consumers. Thus, Francis *et al.,* (2005) and McCarthy *et al.,* (2017) revealed that the sensory perception of fluid milk is heavily influenced by the balance of its macronutrient components (fat, lactose, and protein). These latter demonstrated that opacity, thickness, mouth coating, viscosity, milk fat flavor, and yellow color increased with fat content. That supports the present study sensory analysis of raw milk in which the light-yellow color and slight fat odor of raw milk corroborate with the suitable fat content recorded in the present study findings above.

Furthermore, high fat, fatty acids, and phospholipids contents also contribute to enhancing milk flavor. The fluid milk flavor derives from the steady state between diverse components such as organic acids, alcohols, amines, ester, carbonyl, and sulfur compounds in interaction with proteins and lipids (Vierling, 2003). Raw cow milk is recognized to be less viscous than animal and human milk (Alais, 1984).

The intensity of yellow color in raw cow milk is proportionally related to the content of protein (casein), carotene and fat, the size of fat globules, and depends on animal breed, feed, health, size of fat globules, and fat content. It is reported that the naturally slightly sweet taste of milk results from its lactose content (Vierling, 2003). That supports he present study result where the lactose content in raw milk is significantly higher and what provides this sweet taste noted by consumers than that of reconstituted milk samples.

Overview of milk hygienic quality

Most of the raw milk samples contained target microbes which exceeded the microbiological standard limits.

TAMF count in raw milk was high owing to the milk handling technique on the farm. Indeed, in the practice field, milkers collected the freshly drawn milk using sometimes poorly cleaned milk containers (plastic utensils, tank) and hands, as described in studies in Burkina Faso and other countries (Gemechu and Amene, 2016; Kazienga *et al.,* 2016). Hence by those pathways combined with the milking environment, the risk of microbial contamination is higher. In elsewhere literature, Millogo *et al.,* (2010, 2018); Gemechu and Amene (2016); Assouhoun-Djeni *et al.,* (2020); Compaoré *et al.,* (2021) and Boma *et al.,* (2022) found, respectively, an overall average of total bacteria count ranging 6.64-7.00, 5.22-8.66, 4.98-6.53, 6.17-7.23 log CFU/mL, 1.9×10^7 and 7.57×10^5 CFU/mL in raw milk collected from farms, pastures and households. These values were 1,000- to 10,000-fold higher than in milk directly milked from cow teats/udder. Their findings are in agreement with the present study results. This demonstrates that the farms are the first major source of microbial contamination of raw cow milk. According to the TAMF standard of AFSSA (2001), 100% of the raw milk samples were not in compliance with the safety limit ($\leq 10^5$ CFU/mL). The present study TAMF values were widely higher than those reported by Hamiroune *et al.,* (2016) who found 78.9 and 96.2 % of TAMF-contaminated udder milk and milking storage samples from farms, respectively. While in powder milk, all samples (100%) of present study complied with this standard.

In this study, staphylococci were the second highest microbial community particularly encountered and significantly higher in raw milk than in powder milk. However, low values of staphylococci in raw cow milk collected from farms were found at 1.88-1.89 log CFU/mL, and 5.20×10^1 CFU/mL by Millogo *et al.,* (2018) and Boma *et al.,* (2022), respectively. On the other hand, Baran and Adigüzel (2020) found an average of 4.38 log CFU/mL in 60% of their raw milk samples. The present study results are 10-100,000-fold higher than those of the authors mentioned above. The huge presence of staphylococci in the present study raw milk samples could be due to the health state of the cow. Indeed, this was supported by de Oliveira *et al.,* (2011) who revealed that the presence of *Staphylococcus* sp. in raw milk is usually imputable to subclinical and clinical mastitis of infected cows. Thus, in insufficient sanitary conditions coupled with optimal growth conditions, staphylococci can reach a huge count in raw milk (de Oliveira *et al.,* 2011). Interestingly, there was no *Staphylococcus aureus* (pathogenic germ) found across the negative-coagulase test in the present study unlike previous studies cited above. All raw milk samples (100%) were not in compliance with the safety limit regarding *Staphylococcus* sp. (< 10^2 CFU/mL; AFSSA, 2001).

Although yeasts and molds were more predominant in the present study raw milk samples ($1.48x10^3$ CFU/mL, 2.98 log CFU/mL). The present study findings were lower than those found by Gemechu and Amene (2016) (3.76-4.00 log CFU/mL), Baran and Adigüzel (2020) (3.00-5.97 log CFU/mL), Assouhoun-Djeni *et al.,* (2020) (5.10-6.88 log CFU/mL) and Compaoré *et al.,* (2021) (10^1-$7.4x10^4$ CFU/mL). Whereas in the Lim *et al.,* (2023) study, yeasts and molds that occurred in raw cow milk were lower (1.61 log CFU/mL) than the present study results. Yeasts and molds are microbes that can spoil both the flavor and the sanitary quality of fresh cow milk in an uncontrolled process.

They generate mycotoxins-like toxic metabolites which reduce the milk life and represent a potential public health risk (Torkar and Teger, 2008), particularly for rural and peri-urban people of developing countries who consume frequently raw cow milk. On the other hand, Bayili *et al.,* (2019) revealed the activity of yeast species such as *Saccharomyces cerevisiae* and *Candida parapsilosis* contributing to enhancing the flavor of traditional fermented milk in Burkina Faso. Around 90% of raw milk samples were not in compliance with the safety limit regarding yeasts and molds (< 10^2 CFU/mL; AFSSA, 2001). As for coliforms, the present study results (2.91 log CFU/mL and 2.77 log CFU/mL total coliforms and fecal coliforms, respectively) were lower than those found by Gemechu and Amene (2016) (4.91-5.20 logCFU/mL), Assouhoun-Djeni *et al.,* (2020) (4.81-5.73 log CFU/mL), and Baran and Adigüzel (2020) (< 2-6.48 log CFU/mL), but higher than those of Lim *et al.,* (2023) (2.56 log CFU/mL) in fresh raw cow milk. It is well-known that the strong presence of coliforms in raw cow milk denoted several insufficiencies: the contamination of milk by fecal materials, uncleaned cow teats and udder, poor cleaning of milking container, unsanitary conditions of milking environment, cows kept in muddy barns, poor hygienic practices and milker's hand hygiene, contaminated water and cows with clinical coliform mastitis (Gemechu and Amene, 2016; Jayarao *et al.,* 2004). As for powder milk, the reconditioning and storage of powder milk from the original stock for selling could explain the high coliform count. This practice is commonly retrieved in retailers to whom it is very poorly known the hygiene and environmental conditions in which powder milk is reconditioned in packaging. The total coliforms and fecal coliforms counts should not exceed 10^2 CFU/mL in unprocessed milk (AFSSA, 2001). Consequently, the present study experiment revealed that 70 and 100% of raw milk samples were of acceptable quality regarding total coliforms and fecal coliforms standards, respectively. The present study results are similar to those reported by Kouamé-Sina *et al.,* (2010) and Hamiroune *et al.,* (2016) with 22.8 and 32.8% total coliforms- and fecal coliforms-contaminated udder milk from farms, respectively.

This study indicates that raw cow milk complied with most studied physical and chemical standards (except for pH), and displayed a satisfactory sensory quality compared to reconstituted milk samples derived from milk adulteration with water. However, most of the raw cow milk (90-100%) was poor sanitary quality regarding total aerobic mesophilic flora, staphylococci, yeasts and molds, while 70-100% was acceptable quality according to coliforms standards. Moreover, 100% of reconstituted milk samples had a poor quality related to coliforms. These analysis results highlight potentially hazardous products that can pose a serious public health problem for direct consumption by humans and spoil the quality of end-products of dairy if the milk is not sufficiently and adequately processed and/or highly adulterated by adding water. Therefore, it is necessary to raise awareness of good hygiene practices of milkers, monitor the good health of dairy cows, and draw attention to milk adulteration which decreases milk physicochemical properties and increases contamination due to coliforms. Furthermore, further studies need to be carried out for searching staphylococci, enterobacteria, and fungi toxins because of high staphylococci count, although the coagulase test was negative, and analyzing other harmful germs as well as spore-forming bacteria in raw milk and farm environment in this study area.

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