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Physicochemical and Biochemical Quality of Raw Milk Sold in Korhogo Town (North of Côte d'Ivoire)

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Abstract **Original Research Article**

Although the department of Korhogo is a dairy production area, imported milk and dairy products are the most consumed by the local population. To better understand this situation, a study was conducted on the physicochemical and biochemical quality of raw milk marketed in Korhogo town. Thus, 27 samples of raw milk were collected from sellers in the town of Korhogo. Physicochemical and biochemical analyzes of these samples were carried out. In addition, fraudulent samples were counted by determining the rate of wetting and/or skimming. The raw milk produced locally was of good quality since, for the majority of the samples analyzed, the values of the physicochemical and biochemical parameters were within the range of those proposed by the FAO for raw milk. In addition, a minority of sellers (37.04%) of raw milk practiced fraud, and these did so at low rates (< 15%). Ultimately, this raw milk is recommended for consumption from a nutritional point of view. However, this study should be deepened by also evaluating its microbiological quality.

Keywords: Korhogo, raw milk, Physicochemical characteristics, Biochemical characteristics, wetting, skimming.

INTRODUCTION

Milk is a major component of our daily life; it occupies a strategic place in human nutrition and is an important balanced source of basic nutrients (proteins, carbohydrates and lipids), vitamins and minerals [1, 2]. Despite its nutritional value, in Côte d'Ivoire, the dairy sector is still very embryonic. The low productivity and lack of competitiveness of the animal resources sub-sector limit local milk production. In 2014, it contributed 14.6% to total national production according to data from the Department of Planning, Statistics and Programs (DPSP) of the Ministry of Animal and Fishery Resources. It is subject to two main constraints, namely the low valuation of pastoral resources and institutional weaknesses in the coordination and management of the sector [3].

Because of these constraints, the national dairy sector remains characterized by a predominance of imports. Indeed, with population growth and the emergence of a middle class, foodstuffs of animal origin, including milk, are becoming more important in the diet of Ivorians. Thus the supply of milk and dairy products was estimated at 151 331 tons in 2009 [4]. As a result, each year, the Ivorian State spends significant financial resources on importing dairy products in order to meet national needs.

In general, consumption of milk and derived dairy products is higher in urban than rural areas. The pastoral populations of the North, because of their diets, consume more milk than those of the South. This milk is most often consumed raw or fermented. Milk production comes from traditional and semi-improved farms in villages, urban and peri-urban areas. Traditional farms are most often located around large cities and in the north of the country, which is home to 70% of the cattle population [5].

Korhogo, located in the North of Côte d'Ivoire, is an area of production of cow's milk. However, imported milk and dairy products dominate the local market, as they are the most consumed by the population. Could the low competitiveness of the dairy sector be due to the poor quality of the milk produced? Very little research has been conducted to answer this question. Thus, this study was conducted to assess the physicochemical and biochemical quality of raw milk marketed in Korhogo town.

MATERIAL AND METHODS

Biological material

The biological material consisted of raw cow's milk marketed in Korhogo town. This town is located in the north of the Côte d'Ivoire (latitude 9°27'41" north, longitude 5°38'19" west), 635 km from Abidjan [7].

Sampling raw milk

Milk sample collections were carried out in November 2021. The samples were purchased from raw milk sellers encountered at random, at the large market and at various points of sale in Korhogo town (Table 1). One liter of milk was collected from each seller in a sterile bottle. A total of 27 raw milk samples were taken for this study.. The samples were transported directly to the laboratory in a cooler containing vials of dry ice. In order to avoid milk spoilage, the time between collection and the first analyzes did not exceed 24 hours. Before each sampling for the different analyses, the sample in the bottle was shaken carefully to make the content homogeneous.

Table 1: Number of raw milk sellers and their location

Location	Number of raw milk sellers
Large market	10
Cattle market	03
Kassirimé*	01
Small market of Soba*	02
New neighborhood*	01
Itinerant**	10
Total	27

*Kassirimé, Soba and New Neighborhood are neighborrhoods in Korhogo town
** Fresh milk sellers who roam the neighborhoods of Korhogo town

Physicochemical parameters determination of raw milk

Freezing point

The freezing point of milk was determined in a horizontal freezer (SNAS-375, Nasco, 194 L) using a thermometer (62532, Lacor, -10°C to 110°C) with an accuracy of ± 0.01°C. As soon as the first ice crystals appeared, the exact temperature was read directly on the graduated scale of the thermometer and the result was expressed in degrees Celsius (°C).

Volumic mass

Milk volumic mass was determined using a pycnometer (Dixon Glass, 25 ml) according to the gravimetric method described by standard NF V04-204 [7]. Volumic mass at 20°C (ρ20) in kg/m^3 or g/l was calculated as follows:

$\rho_{20} = 997{,}0 \times [(M_2 - M_0)/(M_1 - M_0)] + 1{,}2 \ldots.$ (1)

Where M_0, M_1 and M_2 represent the masses (in g) of the pycnometer respectively empty, filled with water and filled with oil; the values 997.0 and 1.2 are the volumic masses (in kg/m^3) of water at 20°C and air, respectively.

Viscosity

The viscosity of the milk was determined using a viscometer tube (type 501, Ubbelohde) based on the principle of gravity. The value of the viscosity (η) in mPa.s was calculated as follows:

$\eta\ (\mathrm{mPa.s}) = 10 \times k \times \rho_{20} \times t$ …………………… (2)

With k: gravity calibration constant of the viscometer tube; ρ20: volumic mass at 20°C in g/l of milk; t: gravity flow time (s); 10: conversion factor.

Density

Density was measured using a thermo-lactodensimeter (AD516, Agridev) which gives both the temperature and the density of the sample. If the temperature is 20°C, the float level corresponds to the graduation of the Density reading. Otherwise:

$\text{Density} = D_{read} + [0{,}2 \times (T_{read} - 20)]$ ………… (3)

D_{read}: density value read on the lactodensimeter ; T_{read}: Temperature read on the thermometer ; 0.2: correction coefficient.

pH

The pH of the milk was determined according to the potentiometric method using a pH meter (HI 8915, Hanna Instruments) previously calibrated with two buffer solutions pH=4 and pH=7. The pH value at 20°C was read directly on the display screen of the device.

Dornic acidity

The determination of dornic acidity was based on titration of acidity with sodium hydroxide (N/9) in the presence of phenolphthalein as a colored indicator, according to standard NF 04-206 [8]. The number of ml of soda used was read on the graduated burette. The titratable acidity value, expressed in degrees Dornic (°D), was calculated by the following expression:

$\text{Dornic acidity (°D)} = 10 \times V_{NaOH}$ ……………….. (4)

With V_{NaOH} is the volume (in ml) of Dornic soda (N/9) poured to have the turn of the indicator.

Biochemical parameters determination of raw milk

Fat content

The milk fat content was quantified using a butyrometer (3280, Funke Gerber), according to Gerber's acido-butyrometric method defined by standard ISO 19662 [9]. The graduations corresponding to the lower and upper levels of the lipid column have been denoted (A) and (B), respectively. And the fat content, expressed in g/l, was equal to (B – A).

Dry matter and defatted dry matter contents

The dry matter content was determined by drying the milk in an oven (UN75, Memmert, +300°C) using the gravimetric method described by standard ISO 6731 [10]. The dry matter (DM) and defatted dry matter (DDM) contents, expressed in g/l of milk, were calculated using the following formulas:

$\mathrm{DM} = (\mathrm{M}_1 - \mathrm{M}_0) \times 1000/\mathrm{V}$ ………………… (5)

$\mathrm{DDM} = \mathrm{DM} - \mathrm{MF}$ ……………….…………… (6)

Where M_0 = empty capsule mass (in g); M_1 = mass (in g) of the capsule and residue after drying and cooling; V = volume (in ml) of milk test portion; MF= milk fat content (in g/l).

Ash content

The ash content was determined by incineration in a muffle furnace (R-3 L, JP Selecta) of the milk dry matter of according to the method proposed by standard NF V04-208 [11]. The ash content (AC), expressed in g/l, was obtained as follows:

$\mathrm{AC}\ (\mathrm{g/l}) = (\mathrm{M}_1 - \mathrm{M}_0) \times 1000/\mathrm{V}$ …………… (7)

With M_0 = empty capsule mass (in g); M_1 = mass of the capsule + the ashes (in g); and V = volume (in ml) of milk test portion.

Protein content

The total protein content of milk was evaluated by the Kjeldahl method of standard ISO 8968-1 [12]. It consisted in mineralizing the nitrogen on a Bunsen burner in the presence of 95% sulfuric acid, distilling the ammonia using a Kjeldahl distillation apparatus, after adding sodium hydroxide at 400 g/ l, and, dosing the ammonia with sulfuric acid at 0.05 mol/l in the presence of phenolphthalein as a colored indicator. After that, the number of ml of H_2SO_4 used was carefully read on the burette and the nitrogen content (in g/l) was determined by the following formula:

$\mathrm{Nitrogen}\ (\mathrm{g/l}) = \frac{2 \times \mathrm{C_{H_2SO_4}} \times (\mathrm{V_{H_2SO_4}} - \mathrm{V_b}) \times \mathrm{M_N}}{\mathrm{V}} = 0{,}7 \times (\mathrm{V_{H_2SO_4}} - \mathrm{V_b})$ ……………………….. (8)

V_b et $V_{H_2SO_4}$: volumes (in ml) of sulfuric acid used for the determination, respectively, of the blank and the sample; $C_{H_2SO_4}$: concentration of sulfuric acid= 0,05 mol/l; M_N : atomic molar mass of nitrogen = 14.007 g/mol; V: volume of the milk test sample = 2 ml.

The total protein content (in g/l) was estimated by multiplying the nitrogen content by a conversion constant = 6.38.

Carbohydrate content

The total carbohydrate content was determined according to the formula proposed by AOAC [13]:

$\text{Total carbohydrates}\ (g/l) = \mathrm{DM} - (\text{Ashes} + \text{Proteins} + \text{Lipids})$ ……………………. (9)

Where DM: dry matter content (g/l).

Searching for fraud in raw milk

This part of the study focused on two types of fraud, in particular: wetting, fraud by adding water to the milk, and skimming, fraud by subtracting part of the milk fat. They were evaluated according to the method used by Codou [14].

Wetting rate

Wetting causes an increase in the freezing point. The proportion of added water was evaluated based on the average value of the freezing point of normal milk, which is -0.55°C. When the result of the analysis indicated a higher temperature, fraud was presumed. The percentage of water added to the milk was calculated approximately by the following formula:

$\text{Wetting}\ (\%) = [(0{,}55 - \Delta)/0{,}55] \times 100$ ……. (10)

Where Δ represents the freezing point of the sample taken in absolute value.

Skimming rate

The fat content of partly skimmed milk decreases. The skimming was calculated by comparison with the minimum fat content allowed in raw milk, which is 25 g/l for the Senegalese standard. When the analysis result indicated a lower content, fraud was presumed. The skimming rate was given approximately by the following formula:

$\text{Skimming}\ (\%) = [(25 - \mathrm{M})/25] \times 100$ ……….. (11)

Where M is the fat content of the suspect sample.

During simultaneous skimming and wetting of milk, the wetting rate (W) was first calculated. The quantity of non-wet milk in the sample was then 100 – W; and the quantity M' of butter in the non-wet milk was:

$\mathrm{M}' = [(\mathrm{M} \times 100)/(100 - \mathrm{W})]$ ………………….. (12)

With M representing the quantity of fat (in g/l) in the analyzed milk.

Then, the formula (11) was used to calculate the skimming rate as follows:

$\text{Skimming}\ (\%) = [(25 - \mathrm{M}')/25] \times 100$ ……… (13)

Proportion of suspect samples

For a type of fraud (wetting and/or skimming), the proportion of suspect samples (PSS), expressed in %, was calculated according to the formula below:

$$\text{PSS}\ (\%) = \frac{\text{Number of samples suspected of fraud}}{\text{Total number of samples analyzed}} \times 100 \ \ldots..\ (14)$$

Statistical analysis of data

The results of the physicochemical and biochemical analyzes were expressed by the mean ± standard deviation, then subjected to the analysis of variance (ANOVA) in order to verify the existence of significant differences between the means. ANOVA was followed by Tukey's HSD (Honestly Significant Difference) test to rank means. The chi-square ($\chi2$) test was applied to the calculated proportions to assess the significance of the difference between them. All these statistical tests were performed using XLSTAT 2014 software, and the statistical significance was set at $p < 0.05$.

RESULTS

Physicochemical characteristics of raw milk

Table 2 presents the results of the physicochemical analyzes of the raw milk samples. The pH of the 27 samples was not significantly different ($p > 0.05$), with values between 6.70 and 6.77, and an overall mean of 6.74 ± 0.03. The other physicochemical parameters showed a significant difference ($p < 0.05$) between the milk samples. Indeed, the freezing point was between - 0.65 and - 0.47 °C. Samples E8, E9, E10, E14, E16, E17, E18 and E19 had the highest values (> – 0.55°C); whereas the lowest value (-0.65°C) was observed for samples E12 and E13. Volumic mass and density ranged from 1020.30 to 1052.78 kg/m^3 and 1.019 to 1.051, respectively. Samples E4 and E15 had the highest volumic masses (1050.57 ± 2.51 and 1052.78 ± 2.70 kg/m^3) and densities (1.049 ± 0.003 and 1.051 ± 0.003). The viscosity oscillated between 1.54 and 2.67 mPa.s. The value of sample E14 (1.54 ± 0.02 mPa.s) was the lowest. As for the acidity, it was between 16.13 and 17.53 °D. Samples E3, E4, E15 and E21 had the highest values (respectively 17.37 ± 0.15; 17.43 ± 0.49; 17.53 ± 0.31 and 17.33 ± 0.50°D), contrary to samples E8, E9, E17 and E18 whose values (16.20 ± 0.20; 16.13 ± 0.31; 16.17 ± 0.15 and 16.20 ± 0.20°D, respectively) were the lowest.

Biochemical characteristics of raw milk

The results of the biochemical analysis of the raw milk samples are recorded in Table 3. In terms of the defatted dry matter content, the differences between the 27 samples were not statistically significant (p > 0.05), although the values varied between 84.15 and 94.5 g/l with an overall mean 88.65 ± 3.51 g/l. However, the other biochemical parameters were significantly different ($p < 0.05$) between the samples. The dry matter content was between 109.79 and 135.23 g/l. Samples E11 and E13 had the highest values (132.47 ± 3.37 and 135.23 ± 3.49 g/l) contrary to samples E4, E14 and E15 which had values (109.79 ± 3.05; 113.67 ± 2.40 and 109.96 ± 1.71 g/l, respectively) the lowest. The ash content varied from 6.57 to 8.60 g/l. The contents of samples E4, E9 and E19 (respectively 8.60 ± 0.37; 8.58 ± 0.48 and 8.58 ± 0.10 g/l) were the highest; whereas that of sample E13 (6.57 ± 0.38 g/l) was the lowest. The protein content fluctuated between 30.58 and 41.11 g/l. Sample E14 had the highest content (41.11 ± 0.94 g/l); while that of sample E11 (30.58 ± 0.56 g/l) was the lowest. The fat content was between 19.17 and 44.33 g/l. The fat contents of samples E11, E12 and E13 (44.33 ± 3.21; 43.67 ± 4.04 and 43.33 ± 3.21 g/l, respectively) were the highest; contrariwise, those of samples E4, E14 and E15 (22.90 ± 0.56; 19.17 ± 1.04; 22.00 ± 1.00 g/l) were the lowest. As for the carbohydrate content, it was between 42.13 and 50.80 g/l. Sample E11 had the highest content (50.80 ± 0.61 g/l); whereas those of the E4 and E15 samples (42.13 ± 1.80 and 42.23 ± 2.08 g/l) were the lowest.

Searching for suspect raw milk

Table 4 summarizes the results of the search for suspect (or abnormal) raw milk samples. The results showed that the majority of the samples examined (70.37%) had freezing point values within the standard (less than or equal to -0.55°C), while 29.63% had abnormal values. (greater than -0.55°C). They also indicated that most of the samples (88.89%) had fat contents conforming to the standard (equal to or greater than 25 g/l), while only 11.11% had contents below this standard.

Wetting and skimming rates of suspect raw milks

The rates of wetting and skimming of the suspect samples are recorded in Table 5. Measurement of the freezing point, greater than -0.55°C, makes it possible to assess the quantity of water fraudulently added to the milk (wetting rate). The results revealed that seven samples were suspected of wetting with freezing point values ranging from -0.52 to -0.48°C. These values corresponded to quantities of water fraudulently added to the milk varying from 5.45 to 12.73%. The determination of the fat content, less than 25 g/l, makes it possible to estimate the skimming rate. The results indicated that two samples were suspected skimming with fat contents of 22.00 and 22.90 g/l corresponding to skimming rates of 12.00 and 8.40%, respectively. In addition, a milk sample was suspected of simultaneous wetting and skimming with a freezing point of -0.47 and a fat content of 19.17 g/l. Its wetting and skimming rates were 14.55% and 10.27% respectively.

DISCUSSION

The pH is a good indicator of the freshness of the milk. Indeed, the normal pH of fresh cow's milk varies between pH 6.6 and 6.8 [15]. The pH of the 27 raw milk samples was statistically identical ($p > 0.05$). The samples were fresh since their pH is between 6.70 and 6.77. These values are quite close to those of El Marnissi *et al*. [16] who obtained a pH of 6.6 for raw milk in

Morocco. The freshness of the milk samples analyzed would be due to the fact that the points of sale are supplied daily with cow's milk collected on the farm. As for the acidity, it was between 16.13 and 17.53 °D and complies with the AFNOR standard [17] set between 16 and 18 °D for cow's milk. Likewise, these values confirm the freshness of the milk samples analyzed. The acidities of the samples are close to those of Mouna [18] who obtained values that vary between 11.71°D and 17.25°D. The variabilities of the pH and the titratable acidity of raw milk are linked to the hygienic conditions during milking, to the total microbial flora and to its metabolic activity [19].

Table 2: Physicochemical parameters of raw milk

Milk sample	Freezing point (°C)	Volumic masse (kg/m^3)	Viscosity (mPa.s)	Density	pH	Acidity (°D)
E1	-0.60 ± 0.03^{bc}	1031.78 ± 1.68^{b}	2.53 ± 0.08^{a}	1.030 ± 0.002^{b}	6.71 ± 0.02^{a}	17.10 ± 0.26^{abc}
E2	-0.62 ± 0.03^{cd}	1029.53 ± 1.75^{b}	2.55 ± 0.19^{a}	1.028 ± 0.002^{b}	6.74 ± 0.03^{a}	16.40 ± 0.53^{def}
E3	-0.57 ± 0.02^{b}	1029.90 ± 1.15^{b}	2.54 ± 0.16^{a}	1.029 ± 0.001^{b}	6.71 ± 0.01^{a}	17.37 ± 0.15^{a}
E4	-0.62 ± 0.07^{cd}	1050.57 ± 2.51^{a}	1.90 ± 0.04^{cd}	1.049 ± 0.003^{a}	6.70 ± 0.02^{a}	17.43 ± 0.49^{a}
E5	-0.60 ± 0.04^{bc}	1030.14 ± 1.80^{b}	2.50 ± 0.10^{a}	1.029 ± 0.002^{b}	6.71 ± 0.01^{a}	17.17 ± 0.32^{abc}
E6	-0.58 ± 0.04^{bc}	1030.33 ± 0.58^{b}	2.63 ± 0.32^{a}	1.029 ± 0.001^{b}	6.72 ± 0.03^{a}	17.27 ± 1.14^{ab}
E7	-0.58 ± 0.04^{bc}	1031.00 ± 1.00^{b}	2.50 ± 0.10^{a}	1.030 ± 0.001^{b}	6.73 ± 0.02^{a}	16.80 ± 0.20^{bcd}
E8	-0.51 ± 0.04^{a}	1021.78 ± 4.15^{c}	2.05 ± 0.13^{bcd}	1.020 ± 0.004^{c}	6.77 ± 0.02^{a}	16.20 ± 0.20^{f}
E9	-0.48 ± 0.05^{a}	1020.30 ± 2.04^{c}	2.14 ± 0.05^{b}	1.019 ± 0.002^{c}	6.77 ± 0.01^{a}	16.13 ± 0.31^{f}
E10	-0.50 ± 0.03^{a}	1021.00 ± 4.40^{c}	2.07 ± 0.10^{bc}	1.020 ± 0.004^{c}	6.76 ± 0.02^{a}	16.27 ± 0.31^{ef}
E11	-0.58 ± 0.02^{bc}	1030.26 ± 0.65^{b}	2.56 ± 0.19^{a}	1.029 ± 0.001^{b}	6.74 ± 0.02^{a}	16.53 ± 0.50^{def}
E12	-0.65 ± 0.07^{d}	1031.57 ± 1.91^{b}	2.53 ± 0.15^{a}	1.030 ± 0.002^{b}	6.75 ± 0.04^{a}	16.60 ± 0.87^{def}
E13	-0.65 ± 0.08^{d}	1032.37 ± 3.27^{b}	2.50 ± 0.11^{a}	1.031 ± 0.003^{b}	6.75 ± 0.03^{a}	16.47 ± 0.64^{def}
E14	-0.47 ± 0.02^{a}	1029.97 ± 1.02^{b}	1.54 ± 0.02^{e}	1.029 ± 0.001^{b}	6.76 ± 0.02^{a}	16.47 ± 0.15^{def}
E15	-0.62 ± 0.06^{cd}	1052.78 ± 2.70^{a}	1.87 ± 0.05^{d}	1.051 ± 0.003^{a}	6.70 ± 0.02^{a}	17.53 ± 0.31^{a}
E16	-0.49 ± 0.03^{a}	1020.93 ± 4.74^{c}	2.10 ± 0.17^{b}	1.020 ± 0.005^{c}	6.76 ± 0.02^{a}	16.27 ± 0.31^{ef}
E17	-0.50 ± 0.02^{a}	1021.66 ± 2.86^{c}	2.09 ± 0.08^{bc}	1.020 ± 0.003^{c}	6.77 ± 0.01^{a}	16.17 ± 0.15^{f}
E18	-0.52 ± 0.03^{a}	1023.57 ± 6.41^{c}	2.10 ± 0.08^{b}	1.022 ± 0.006^{c}	6.77 ± 0.02^{a}	16.20 ± 0.20^{f}
E19	-0.52 ± 0.02^{a}	1021.95 ± 3.87^{c}	2.01 ± 0.12^{bcd}	1.021 ± 0.004^{c}	6.76 ± 0.02^{a}	16.40 ± 0.20^{def}
E20	-0.58 ± 0.02^{bc}	1029.40 ± 3.67^{b}	2.54 ± 0.05^{a}	1.028 ± 0.004^{b}	6.74 ± 0.02^{a}	16.73 ± 0.31^{cde}
E21	-0.60 ± 0.05^{bc}	1029.63 ± 1.59^{b}	2.60 ± 0.26^{a}	1.028 ± 0.002^{b}	6.71 ± 0.02^{a}	17.33 ± 0.50^{a}
E22	-0.57 ± 0.03^{b}	1030.67 ± 1.53^{b}	2.67 ± 0.21^{a}	1.029 ± 0.002^{b}	6.72 ± 0.01^{a}	17.20 ± 0.40^{abc}
E23	-0.58 l ± 0.03^{bc}	1029.83 ± 2.93^{b}	2.58 ± 0.08^{a}	1.028 ± 0.003^{b}	6.72 ± 0.04^{a}	17.27 ± 0.76^{ab}
E24	-0.57 ± 0.02^{b}	1030.07 ± 1.90^{b}	2.61 ± 0.21^{a}	1.029 ± 0.002^{b}	6.76 ± 0.03^{a}	16.40 ± 0.53^{def}
E25	-0.57 ± 0.03^{b}	1032.00 ± 1.00^{b}	2.60 ± 0.10^{a}	1.031 ± 0.001^{b}	6.75 ± 0.02^{a}	16.60 ± 0.40^{def}
E26	-0.57 ± 0.01^{b}	1030.26 ± 0.65^{b}	2.56 ± 0.19^{a}	1.029 ± 0.01^{b}	6.76 ± 0.02^{a}	16.60 ± 0.20^{def}
E27	-0.58 ± 0.03^{bc}	1030.86 ± 2.21^{b}	2.59 ± 0.10^{a}	1.030 ± 0.002^{b}	6.75 ± 0.02^{a}	16.50 ± 0.30^{def}
Overall average	-0.57 ± 0.06	1029.78 ± 7.74	2.35 ± 0.32	1.028 ± 0.008	6.74 ± 0.03	16.72 ± 0.58

In the same column, means with different letters (a, b, c, d, e, f) are significantly different (Turkey's HSD test, p < 0, 05).

Table 3: Biochemical parameters of raw milk expressed in g/l

Milk sample	Dry matter content	Defatted dry matter	Ash content	Protéin content	Fat content	Carbohydrates content
E1	127.37 ± 1.72^{bc}	91.37 ± 2.09^{a}	7.10 ± 0.40^{defg}	38.03 ± 0.15^{ab}	36.00 ± 2.00^{b}	46.23 ± 2.51^{bcd}
E2	126.09 ± 2.31^{cde}	89.42 ± 2.17^{a}	7.34 ± 0.57^{cdefg}	35.35 ± 0.64^{bcdefg}	36.67 ± 2.52^{b}	46.73 ± 2.07^{bcd}
E3	126.95 ± 4.41^{bc}	90.29 ± 1.92^{a}	7.14 ± 0.55^{defg}	35.58 ± 0.94^{bcdef}	36.67 ± 2.52^{b}	47.57 ± 1.55^{abcd}
E4	109.79 ± 3.05^{g}	86.89 ± 3.19^{a}	8.60 ± 0.37^{a}	36.15 ± 1.03^{abcde}	22.90 ± 0.56^{c}	42.13 ± 1.80^{e}
E5	125.39 ± 6.80^{cde}	88.73 ± 4.96^{a}	7.55 ± 0.64^{bcde}	33.78 ± 1.05^{bcdefg}	36.67 ± 2.08^{b}	47.40 ± 3.39^{abcd}
E6	125.53 ± 1.91^{cde}	89.37 ± 0.79^{a}	7.37 ± 0.12^{cdef}	35.27 ± 0.88^{bcdefg}	36.17 ± 1.76^{b}	46.73 ± 1.58^{bcd}
E7	126.34 ± 0.57^{cd}	90.34 ± 1.56^{a}	7.24 ± 0.48^{cdefg}	36.57 ± 0.60^{abcde}	36.00 ± 1.00^{b}	46.53 ± 1.55^{bcd}
E8	119.52 ± 7.04^{f}	85.18 ± 5.99^{a}	7.58 ± 0.54^{bcde}	33.60 ± 0.96^{bcdefg}	34.33 ± 2.08^{b}	44.00 ± 4.77^{de}
E9	118.79 ± 2.76^{f}	85.79 ± 0.13^{a}	8.58 ± 0.48^{a}	32.71 ± 1.10^{cdefg}	33.00 ± 2.65^{b}	44.50 ± 0.50^{cde}
E10	121.41 ± 3.31^{def}	88.21 ± 5.44^{a}	7.68 ± 0.64^{bcde}	35.50 ± 0.75^{bcdefg}	33.20 ± 2.31^{b}	45.03 ± 4.05^{bcde}
E11	132.47 ± 3.37^{a}	88.13 ± 0.58^{a}	6.75 ± 0.35^{fg}	30.58 ± 0.56^{g}	44.33 ± 3.21^{a}	50.80 ± 0.61^{a}
E12	131.34 ± 2.40^{ab}	87.67 ± 1.69^{a}	7.01 ± 0.04^{efg}	32.40 ± 0.90^{defg}	43.67 ± 4.04^{a}	48.27 ± 0.76^{abc}
E13	135.23 ± 3.49^{a}	91.90 ± 0.40^{a}	6.57 ± 0.38^{g}	36.76 ± 0.95^{abcd}	43.33 ± 3.21^{a}	48.57 ± 0.95^{ab}

Milk sample	Dry matter content	Defatted dry matter	Ash content	Protéin content	Fat content	Carbohydrates content
E14	113.67 ± 2.40^{g}	94.50 ± 3.06^{a}	8.02 ± 0.16^{abc}	41.11 ± 0.94^{a}	19.17 ± 1.04^{c}	45.37 ± 3.59^{bcde}
E15	109.96 ± 1.71^{g}	87.96 ± 1.12^{a}	8.22 ± 0.27^{ab}	37.51 ± 0.70^{abc}	22.00 ± 1.00^{c}	42.23 ± 2.08^{e}
E16	121.30 ± 7.76^{ef}	88.20 ± 5.30^{a}	7.56 ± 0.31^{bcde}	35.78 ± 1.08^{bcdef}	33.10 ± 2.48^{b}	44.87 ± 3.92^{bcde}
E17	121.43 ± 5.87^{def}	87.43 ± 5.03^{a}	7.66 ± 0.14^{bcde}	34.53 ± 0.90^{bcdefg}	34.00 ± 1.00^{b}	45.23 ± 4.22^{bcde}
E18	119.48 ± 4.21^{f}	84.15 ± 3.34^{a}	7.82 ± 0.24^{abcd}	31.60 ± 0.71^{efg}	35.33 ± 3.21^{b}	44.73 ± 3.36^{bcde}
E19	119.25 ± 4.01^{f}	84.75 ± 4.51^{a}	8.58 ± 0.10^{a}	32.13 ± 0.81^{defg}	34.50 ± 0.50^{b}	44.03 ± 4.32^{de}
E20	123.17 ± 3.66^{cdef}	86.17 ± 1.90^{a}	7.78 ± 0.21^{bcde}	31.15 ± 0.71^{fg}	37.00 ± 2.00^{b}	47.23 ± 1.31^{abcd}
E21	125.52 ± 3.00^{cde}	88.85 ± 1.55^{a}	7.70 ± 0.41^{bcde}	33.78 ± 0.70^{bcdefg}	36.67 ± 1.53^{b}	47.37 ± 1.88^{abcd}
E22	125.41 ± 7.02^{cde}	89.31 ± 4.34^{a}	7.47 ± 0.38^{bcdef}	35.77 ± 0.66^{bcdef}	36.10 ± 2.69^{b}	46.07 ± 5.28^{bcde}
E23	125.08 ± 3.10^{cde}	88.41 ± 4.85^{a}	7.61 ± 0.45^{bcde}	34.00 ± 0.95^{bcdefg}	36.67 ± 2.08^{b}	46.80 ± 3.56^{bcd}
E24	126.47 ± 4.74^{bc}	89.81 ± 3.71^{a}	7.11 ± 0.11^{defg}	35.67 ± 3.55^{bcdef}	36.67 ± 2.08^{b}	47.03 ± 1.38^{abcd}
E25	126.75 ± 2.02^{bc}	91.09 ± 0.96^{a}	7.05 ± 0.12^{defg}	36.64 ± 0.90^{abcd}	35.67 ± 2.08^{b}	47.40 ± 1.31^{abcd}
E26	125.68 ± 4.86^{cde}	89.48 ± 1.90^{a}	7.47 ± 0.40^{bcdef}	34.12 ± 0.60^{bcdefg}	36.20 ± 3.02^{b}	47.90 ± 1.66^{abcd}
E27	126.06 ± 2.81^{cde}	90.06 ± 1.98^{a}	7.61 ± 0.14^{bcde}	36.08 ± 0.49^{bcdef}	36.00 ± 1.00^{b}	46.37 ± 2.07^{bcd}
Overall average	123.54 ± 6.79	88.65 ± 3.51	7.56 ± 0.60	34.89 ± 2.44	34.89 ± 5.90	46.19 ± 2.97

In the same column, means with different letters (a, b, c, d, e, f, g) are significantly different (Turkey's HSD test, $p < 0, 05$).

Table 4: Search for suspect samples (or abnormal)

Parameters	Terms	Number of samples	Proportion of samples (%)	Statistics
				***P*-value**
Freezing point (°C)	≤ -0.55	19	70.37	< 0.0001
	≥ -0.55	08	29.63	
Fat content (g/l)	< 25	03	11.11	< 0.0001
	≥ 25	24	88.89	

Table 5: Wetting and/or skimming Rates of suspect samples

Type of fraud	Freezing point(°C)	Fat content (g/l)	Number of samples	Wetting rate (%)	Skimming rate (%)
Wetting	-0.52	-	01	5.45	-
	-0.51	-	01	7.27	-
	-0.50	-	02	9.09	-
	-0.49	-	01	10.91	-
	-0.48	-	02	12.73	-
Skimming	-	22.00	01	-	12.00
	-	22.90	01	-	8.40
Wetting and skimming	-0.47	19.17	01	14.55	10.27

Apart from the pH, the other physicochemical parameters showed a significant difference ($p < 0.05$) between the samples. The freezing point is a very useful parameter in quality assessment; because it provides information on the addition of water to milk. The freezing point value of the samples varied between -0.65°C and -0.47°C. It is in the same order (-51.60) as that obtained by Bermúdez-Aguirre *et al*., [20] for raw milk. The viscosity of the raw milk samples analyzed varied between 1.54 and 2.67 mP.a.s. As for the density, it varied between 1.019 and 1.051. These results are within the range of cow's milk from the Bordj El Ghedir region of Algeria, which had recorded density values between 1.026 and 1.034 [21]. However, the latter reported higher viscosity values (3.1-4.9 mPa.s) than that of this study. Changes in density are caused by factors such as type of fodder, lactation period, fat removal and water addition [22]. The variability of the physicochemical parameters of milk would be due to the breed of cow, seasonal variations, the production area as well as the different operations during and after milking [23].

Concerning the biochemical characteristics, at the level of the defatted dry matter content, the differences between the samples were not statistically significant ($p > 0.05$), although the values varied between 84.15 and 94.5 g/l. The results are similar to those of Bermúdez-Aguirre *et al*., [20] who obtained 91.5g/l for raw milk. The dry matter, ash, protein, fat and carbohydrate contents were significantly different ($p < 0.05$) between the samples. The dry matter content of the samples was between 109.79 and 135.23. It is comparable to the value of 124.29 g/l recorded by Ainouche and Bouslah [24] for raw milk from cows raised in Algeria. The dry matter content of fresh milk depends on diet, climate, but also on breed [25]. The ash content (6.57-8.60) is quite close to the values of 7.57 g/l and 7.35 g/l, obtained respectively by Bouzid and Labidi [26] and Meftah *et al*., [23] for milk from cows raised in Algeria. It is influenced by the animal's breed, stage of lactation and diet [25]. The protein content (30.58-41.11 g/l) is close to that reported by Gemechu and Amene [27] which had values between 38.44 and 41.40 g/l for raw cow's milk produced in the South West of Ethiopia. The fat content of the samples varied between 19.17 and 44.33 g/l. It does not agree with the range of 28.5 to 32.5 g/l reported by the Association Française de Normalization [17]. However, it is quite close to the average value of 31.4 g /l found by Labioui *et al*., [28] in Morocco and that of 44.97 g/l reported by Kalandi *et al*. [29] in Senegal. The variability in fat content depends on factors such as climatic conditions, stage of lactation and diet [30]. The carbohydrate content of the samples fluctuated between 42.13 and 50.80 g/l. It is similar to that obtained by Labioui *et al*., [28] as well as that of Meftah *et al*., [23] who reported values of 43.51 g/l and 50.68 g/l respectively. The main carbohydrate in cow's milk is lactose, which is influenced by energy intake. Most of the milk samples analyzed were of good biochemical quality since their average levels were quite close to the values given by the FAO [15] for raw milk.

Adding water to milk is considered adulteration of the product, and it is intrinsically linked to the freezing point. A freezing point, greater than -0.55°C, makes it possible to assess the quantity of water fraudulently added to the milk (wetting rate). Moreover, a fat content of less than 25 g/l makes it possible to estimate the skimming rate. The search for fraud showed that the majority of the samples examined had freezing point values (70.37%) and fat contents (88.89%) within the standards. However, were suspected of wetting and skimming, 29.63% and 11.11% of the samples. Thus, few sellers of raw milk practiced fraud; and those who did cheat did so at low rates (<15%).

In addition, wetting was more practiced than skimming. These results have the same trend as those of Codou [14] who suspected wetting, 24% samples, and skimming, 6% samples of raw cow's milk analyzed. However, according to Eeckhoutte [31], the detection of most of these frauds is delicate and requires a lot of care during the analyses. In particular, the interpretation of the results consists in comparing the analysis data with the levels considered to be normal. Since milk has a naturally variable composition, setting so-called “normal” levels may seem arbitrary.

CONCLUSION

This study showed that the majority of raw milk samples analyzed complied with FAO standards. However, a minority of raw milk sellers practiced fraud at low rates. To remedy this, milk sellers should be made aware of the consequences of these fraudulent practices on milk quality. In short, the raw milk sold in Korhogo town is recommendable for consumption from a nutritional point of view. However, it would be relevant to assess the microbiological and hygienic quality of this milk.

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