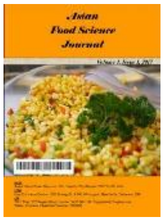

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Physicochemical Evaluation of Bovine Milk in North Central Nigeria

Susan Kingsley Okeke[1*], Moses Enemaduku Abalaka[2], Hussaini Anthony Makun[3] and Jeremiah David Bala[2]

[1]Department of Nutrition and Dietetics, The Federal Polytechnic Bida, Nigeria.
[2]Department of Microbiology, Federal University of Technology, Minna, Nigeria.
[3]Department of Biochemistry, Federal University of Technology, Minna, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author SKO designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed literature searches. Authors MEA, HAM and JDB supervised and managed the research work and read proof the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Introduction: Physiochemical analysis is an important tool to monitor the quality of milk and other dairy products.
Aim: This study was conducted to evaluate the physicochemical quality of the bovine milk in three selected states from the North Central, Nigeria.
Study Design: To determine pH, titratable acidity TTA, specific gravity SG, Viscosity and freezing point FP of cattle milk obtained from 15 Local Government Areas in North Central, Nigeria
Place and Duration of Study: Three states were selected from the North Central Zone of Nigeria which includes Niger, Kwara and Kogi States. A total of the 15 Local Government Areas LGAs. These include; Edati-idati, Agaie, Bosso, Mariga, and Rafi (Niger state), Patigi, Ilorin East, Ilorin West, Ifelodun, and Moro (Kwara state), Okene, Ibaji, Kabba, Idah and Lokoja (Kogi state).The sampled lasted for a year six months.
Methodology: A total of 180 cattle milk samples were collected from local producers and local vendors hawked, stationed in a market and from local milk producers. The pH, TTA, SG, Viscosity,

**Corresponding author: Email: susanokeke@gmail.com;*

FP of the milk samples were determined using pH meter, titration, Lactometer, viscometer, thermistor cryoscope
Results: The range values for pH, TTA, SG, Viscosity and FP of cow milk were 5.20-6.20, 0.09-1.91% lactic acid, 1.026-1.060 g/m/s, 150-184 cp and -0.442 to -0.532°C. There was a significant difference (P<0.05) in pH values of milk product within each state. Out of 15 LGAs of the state, five LGAs milk samples did not conform to 1.027-1.035 g per mL set by World Health Organisation, WHO standard, while four LGAs had <1.020 specific gravity. Milk sampled from Mariga LGA had a highest FP (-0.442±0.007°C) while Edati LGA milk had -0.525±0.003°C lowest freezing point.
Conclusion: The findings revealed that most of the milk samples were adulterated with water and as such are unsafe for consumption.

Keywords: Adulteration; bovine milk; freezing point; physiochemical properties; specific gravity; viscosity.

1. INTRODUCTION

The local production of milk is less than 1% of the total annual demand that has been estimated at 1.45b litres making the total milk consumption in Nigeria less than 10 litre per head whereas the global average is about 40litres per head in South Africa, 50 litres in New Zealand, and 70 litres in the U.S. In order part of Africa, it is 28 litres per head. Average world's annual milk production by country in 2012 was 3.1 million tonnes, while that of Nigeria was 566,000 tonnes; South Africa and Kenya were 3.36 million and 3.73 million respectively. South Africa is able to produce about 6 times more milk than Nigeria with about 42.5% of the number of cows in Nigeria [1].

The domestic production of milk is continuing to be hampered by low milk yields of domestic cattle, low level of cattle nutrition and animal health challenges. About N75 billion is spent annually on the importation of the milk and milk products in Nigeria [2]. This may be as a result of a microbial invasion of their feeds, mastitis and product spoilage. Producers in order to cope with this development, adulterate milk and milk products with different substances such as hard water, plant latex, formalin, sucrose, and starch.

In Nigeria, adulteration and contamination of milk and milk products are mostly practiced by producers and vendors either for financial gain or lack of proper hygienic conditions of processing, storing, transportation and marketing. Some adulterations in this state are done to give a desirable consistency which allows the addition of cereal products such as *fura* which is consumed alongside with it. Again the low or insufficient production of milk during dry season might have pushed local producers to adulterate milk with water. Since the resultant milk products standard of production are not regulated, the different producer provides recipes for theirs. This ultimately leads to the stage that the consumer is either cheated or often becomes the victim of diseases. Moreover, adulteration of milk with water, which is very common not only causes dilution of milk reducing the milk solids, but also involves the risk of introducing germs into the milk, further decreasing its quality. So, it is naturally of great importance that such a valuable and easily-damaged food be delivered to the consumer in a wholesome and unadulterated form. Not only because the abstraction of cream and the adulteration with water diminish the food value of the milk, there is great danger in the latter case of the germs of infectious and contagious diseases being introduced into the milk [3]. According to Faraz et al. [4], an Increased concentration of hard water in milk showed the adverse effect on quality of milk by increasing the acidity, thereby reducing the shelf life of milk. Adulteration of milk can cause the deterioration of dairy product and to ensure milk quality requires the necessity and greater emphasis on regulatory aspects with advanced methods of analysis and monitoring milk production.

One of the ways of monitoring the adulteration/ quality of milk is physicochemical evaluation hence this work objective focuses on the physicochemical assessment of bovine milk produced in selected states of North Central zone of Nigeria.

2. MATERIALS AND METHODS

2.1 Study Areas

The study area is located in the North Central Zone (Middle Belt) of Nigeria. The choice of the study area was as a result of its location in the Middle-belt of Nigeria which has savannah grassland as well as herdsmen favourite place for grazing (characterized with a lot of herds activities)s. Three states were selected from the North Central Zone of Nigeria which includes Niger, Kwara and Kogi States. A total of 15 Local Government Areas were randomly picked. These include; Edati-idati, Agaie, Bosso, Mariga, and Rafi (Niger state), Patigi, Ilorin East, Ilorin West, Ifelodun and Moro (Kwara state), Okene, Ibaji, Kabba, Idah and Lokoja (Kogi state).

2.2 Sampling Method/Sample Collection

A total of 180 cow milk samples comprising 12 samples from each local Government Area were randomly collected. Bovine milk was purchased from local vendors hawked, stationed in a market and from local milk producers. Two hundred (200mL) of milk were aseptically collected and put in sterile bottles. All samples were coded with random numbers for identification and transported into the Laboratory and refrigerated until analyzed in Biochemical Laboratory, Federal University of Technology Minna, Center for Engineering and Biotechnology Research Laboratory-Step-B and International Institute of Tropical Agriculture, Ibadan, IITA.

2.3 Determination of Physicochemical Parameters of Milk and Milk Products

2.3.1 pH

The pH of fresh milk was determined at room temperature (29°C) using a digital pH meter (JENWAY 3505). The pH meter was calibrated with buffer, standards of pH 4 and pH 10 prior to use. Fifty milliliters of 50 mL of each milk samples were placed in a beaker while 20mL of sterile distilled water were added and the mixture was shaken on the rotatory orbital for 30 minutes. The pH of the suspension was then determined by inserting the electrode of the pH meter into the solution and the pH value was read when the reading was stable. The probe of the pH meter was inserted and the pH value was recorded. The probe was rinsed thoroughly with the distilled water before used on the sample pH [5,6].

2.3.2 Titratable acidity (TTA)

Thirty milliliters of each sample: (fresh milk) was homogenized in 9mL sterile diluents peptone water with a blender. This sample was boiled on a hot plate to remove carbon. This was allowed to cool and the initial volume restored by adding sterile distilled water. Ten milliliters aliquot of diluted samples was transferred into a conical flask and a drop of phenolphthalein indicator was added and titrated with a 0.05N NaOH until a pink colour appeared [4]. The titratable acidity was then calculated using below equation

$$\text{Lactic acid} = v_o \times M \times 0.009 \text{ in } 10 \text{ mL}/v$$

Where, v_o =volume of NaOH used,
M =Molarity of NaOH,
v =volume of sample used (ml).

2.3.3 Determination of specific gravity

Specific gravity (S.G) of milk is the ratio of the weights of equal volumes of milk and distilled water at the same temperature. The SG was then calculated using below equation

$$S.G = \frac{\text{Weight of milk}}{\text{Vol of milk density}} \times \text{Temp}$$

The specific gravity was determined using Lactometer a special hydrometer designed for use with milk (Omsons Lactometer 2136 Model) adopting [7]. Samples were mixed gently to avoid incorporation of air into the samples and poured into a measuring cylinder (300-500). The Lactometer was dropped into the milk and allowed to float. The reads of the last Lactometer degree (ºL) just above the surface of the milk (meniscus) and the temperature of the samples were recorded. Since the temperature of the milk was different from the calibration temperature (Calibration temperature was 20°C/60°F) of the lactometer, the temperature was calculated. For each ºC above the calibration temperature 0.2°L was added, for each ºC below calibration temperature, 0.2ºL was subtracted from the recorded lactometer reading.

To Find S.G for milk sample that had Lactometer Readings= 29 and Temp. = 15°C.

$$(\text{Temp C}° \times \frac{9}{5}) + 32 = \text{F}°$$

$$(15 \times \frac{9}{5}) + 32 = 59°\text{F}$$

60-59=1^{o}F, 29-0.1=28.9 (CLR-Correct Lactometer Readings)

$$S.G = \frac{CLR}{1000} + 1 = \frac{28.9}{1000} + 1 = 1.0289$$

2.3.4 Determination of viscosity of milk and milk products

The viscosity of milk and milk products was measured with Brookfield viscometer (DV-II1, Brook-field Engineering Laboratories, MA, USA) using spindle 4. Five hundred milliliters (500 mL) of the samples were poured into the 500 mL beaker of the viscometer. The rotor was immersed into it. The viscometer was then switched on and was allowed to spin at the speed of 100 revolutions per minute (rpm). The resistance of the fluid against the applied speed was measured in centipoise (cp). A value was recorded for all the samples after 3 mins when the dial remained at the same reading [8,9].

2.3.5 Determination of freezing point (FP) of milk and milk products

The freezing point of milk and milk products were determined using the method of Navratilova et al. [7] The freezing point was performed with a thermistor cryoscope (model 6D21 Advanced Instrument, USA). The thermistor cryoscope was regularly calibrated with the standard solution with the freezing point of -0.408 and -0.600. The calibration was verified with the reference solution lactol (-0.512). Freezing points were expressed in degrees centigrade.

Data analysis was performed to derive mean values, standard error, and analysis of variance using one-way ANOVA. Data were graphically represented using Statistical Packages for Social Sciences, SPSS.

3. RESULTS AND DISCUSSION

3.1 pH across the Three Selected States from North Central Zone

The physicochemical properties of bovine milk are presented in Tables 1-3. The pH of fresh milk ranged (%) 5.20-5.85 across the five Local Government Areas (LGAs) in Niger State against 6.10-6.35 and 6.00-6.20 observed in Kwara State and Kogi state. There were significant variation P<0.05 in pH values of milk product within each state however the mean pH value differed slightly across the three states sampled (Table 4). It was observed in this present study that milk from Kwara and Kogi State had higher pH values compared to that of Niger State. It has been said that pH Value higher than 6.60 indicates an increase of milk due to bacterial multiplication [10]. The pH value range 5.20-5.85, 6.10-6.35, and 6.00-6.20 observed for fresh milk from Niger, Kwara and Kogi state did not comply with the above standard. The pH range found in this current study was comparable with the findings (5.0-5.7, 5.85-6.30, 5.60-6.00) in a previous investigation [11,12], Awah et al.[13]. But lower pH of 4.29-4.56 was reported by Chukwendu et al [14].The low pH reported in this work may be due to microbial fermentation. According to Awah et al. 10], a low pH value of 5.5 average may inhibit potential pathogenic organism. A higher pH value was documented to be 6.57, 7.00, 6.59 and 6.93 [15],Tona et al. [16], Fayeye et al.[17], Imran et al. [18]. The higher pH reported by [16] and [17] from Ilorin, Kwara state was due to the fact that the researcher sampled milk from Jersey cattle which were well kept in ranches. Unlike the Fulani cattle (Local breed) from which the present researcher obtained milk samples, they usually practice open grazing system exposing the cattle to poor management practices which could have led to contamination of milk.

3.2 TTA of Bovine Milk across the Three States

The TTA value (%) across the three states range 0.09-0.24, 0.26-1.91, 0.25-3.79 for fresh milk. The TTA of bovine milk across the LGAs of Niger state did not differ P>0.05 however variation existed in TTA of fresh milk from the other state. Fresh milk from Ibaji had the highest TTA while Okene milk had the lowest. The Physicochemical analysis is an important tool to monitor the quality of dairy products. Adulteration of dairy products and to ensure milk quality requires the necessity and greater emphasis on regulatory aspects. The highest TTA % of fresh milk observed was 0.24 from Agaie LGA, Niger state and 0.09 lowest TTA from Ilorin East. The TTA standard according to WHO was set at 0.14-0.16. Some of the TTA values observed in this present study did not conform to this standard. The TTA observed in this current study was comparable with 0.15-0.19, 0.18-0.23, 0.197-0.203, reported by [19,16], Gemechu et al.[10]. On the other hand, Fayeye et al. [17,20] obtained a higher TTA (0.28%, 0.27% lactic acid of cow milk). However, Imran et al. [18] reported a higher TTA of 0.81-1.44%. The high TTA reported by these researchers may be due to the assessment of mastitis cow. Since they sampled mastitis milk. According to Kader et al. [15], mastitis milk had ≥TTA of 0.23%. Fayeye et al. [17] Reveals that lactation timing has an effect on TTA of milk as early lactation can result in higher TTA value. Bacteria that normally develop in raw milk produce more or less of lactic acid. The natural acidity of milk is 0.16 - 0.18%. Figures higher than these signify developed acidity due to the action of bacteria on milk sugar. TTA greater than 0.16% could also indicate milk sample kept at room temperature for a longer period of time under a poor hygienic practices until sold.

Table 1. Physicochemical properties of bovine milk obtained from Niger State

	Agaie	Bosso	Edati	Mariga	Rafi
pH	5.85 ± 0.00^{a}	5.35 ± 1.34^{b}	5.20 ± 0.02^{d}	5.39 ± 0.49^{b}	5.25 ± 0.00^{c}
Titratable acidity	0.24 ± 0.01^{a}	0.20 ± 0.03^{a}	0.21 ± 0.00^{a}	0.20 ± 0.00^{a}	0.22 ± 0.01^{a}
Viscosity (cp)	150.00 ± 3.01^{c}	161.00 ± 3.03^{c}	176.00 ± 3.00^{b}	184.00 ± 3.00^{a}	182.00 ± 4.01^{a}
specific gravity (g/m/s)	1.008 ± 0.34^{d}	1.020 ± 0.13^{b}	1.026 ± 0.10^{a}	1.002 ± 0.10^{e}	1.014 ± 0.09^{c}
Freezing Point (^{o}C)	-0.500 ± 0.003^{b}	-0.503 ± 0.005^{b}	-0.525 ± 0.003^{a}	-0.442 ± 0.007^{d}	-0.462 ± 0.004^{c}

[1] Values are the mean±Standard error of 30 determinations, LGAs=Local Government Area
[2] Different letters of superscript along the rows are significantly different (P<0.05)

Table 2. Physicochemical properties of bovine milk obtained from Kwara State

Locations (LGAs)	Ilorin East	Ilorin West	Ifelodun	Moro	Patigi
pH	$6.35\pm0.56^{a,}$	6.28 ± 0.00^{b}	6.30 ± 0.04^{a}	$6.32\pm0.34^{a,}$	6.10 ± 0.01^{c}
Titratable acidity (%)	0.09 ± 0.01^{d}	0.11 ± 0.01^{c}	0.19 ± 0.02^{a}	0.13 ± 0.01^{c}	0.16 ± 0.04^{b}
Viscosity (cp)	130.00 ± 2.01^{b}	167.00 ± 1.81^{a}	123.00 ± 3.02^{c}	132.00 ± 3.01^{b}	126.00 ± 2.04^{c}
Specific Gravity (g/m/s)	1.037 ± 0.21^{a}	1.025 ± 0.21^{b}	1.027 ± 0.12^{b}	1.029 ± 0.011^{b}	1.034 ± 0.04^{a}
Freezing Point (^{o}C)	-0.532 ± 0.002^{a}	-0.494 ± 0.004^{c}	-0.512 ± 0.006^{b}	-0.529 ± 0.001^{a}	-0.500 ± 0.008^{b}

[1] Values are the mean±Standard error of 30 determinations, LGAs=Local Government Area
[2] Different letters of superscript along the rows are significantly different (P<0.05)

Table 3. Physicochemical properties of bovine milk obtained from Kogi State

	Ibaji	Idah	Kabba	Lokoja	Okene
pH	6.00 ± 0.01^{d}	6.15 ± 0.02^{a}	6.10 ± 0.00^{c}	6.20 ± 0.01^{a}	6.08 ± 0.00^{c}
Titratable acidity (%)	0.19 ± 0.01^{b}	0.16 ± 0.02^{c}	0.18 ± 0.03^{b}	0.14 ± 0.01^{d}	0.11 ± 0.00^{e}
Viscosity (cp)	176.00 ± 1.01^{b}	157.00 ± 1.02^{c}	138.00 ± 2.03^{d}	140.00 ± 3.01^{d}	144.00 ± 1.00^{d}
Specific Gravity (g/m/s)	1.031 ± 0.01^{c}	1.034 ± 0.012^{c}	1.039 ± 0.08^{a}	1.038 ± 0.07^{ab}	1.014 ± 0.00^{d}
Freezing Point (^{o}C)	-0.520 ± 0.003^{a}	-0.456 ± 0.003^{c}	-0.519 ± 0.001^{a}	-0.519 ± 0.007^{a}	-0.499 ± 0.005^{b}

[1] Values are the mean±Standard error of 30 determinations, LGAs=Local Government Area
[2] Different letters of superscript along the rows are significantly different (P<0.05)

Table 4. Titratable acidity of milk and milk products across three states

Location	pH	TTA	*SG*	Viscosity	FP
Niger State LGAs					
Agaiae	5.85 ± 0.00^{c}	0.24 ± 0.01^{a}	1.008 ± 0.34^{f}	150.00 ± 3.01^{c}	-0.419 ± 0.003^{f}
Bosso	5.35 ± 1.34^{d}	0.20 ± 0.03^{a}	1.020 ± 0.13^{f}	161.00 ± 3.03^{c}	-0.523 ± 0.005^{b}
Edati-idati	5.20 ± 0.02^{d}	0.21 ± 0.00^{a}	1.026 ± 0.10^{de}	176.00 ± 3.00^{b}	-0.545 ± 0.003^{a}
Mariga	5.39 ± 0.49^{d}	0.20 ± 0.00^{a}	1.002 ± 0.10^{f}	184.00 ± 3.00^{a}	-0.442 ± 0.007^{e}
Rafi	5.25 ± 0.00^{d}	0.22 ± 0.01^{a}	1.014 ± 0.09^{f}	182.00 ± 4.01^{a}	-0.462 ± 0.004^{d}
Kwara State LGAs					
Ilorin East	6.35 ± 0.56^{a}	0.09 ± 0.01^{f}	1.037 ± 0.21^{ab}	130.00 ± 2.01^{e}	-0.532 ± 0.002^{a}
Ilorin West	6.28 ± 0.00^{b}	0.11 ± 0.01^{e}	1.025 ± 0.21^{e}	167.00 ± 1.81^{c}	-0.474 ± 0.004^{c}
Ifelodun	6.30 ± 0.04^{a}	0.19 ± 0.02^{b}	1.027 ± 0.12^{d}	123.00 ± 3.02^{f}	-0.512 ± 0.006^{b}
Moro	6.32 ± 0.34^{a}	0.13 ± 0.01^{d}	1.029 ± 0.011^{d}	132.00 ± 3.01^{e}	-0.529 ± 0.001^{a}
Patigi	6.10 ± 0.01^{b}	0.16 ± 0.04^{c}	1.034 ± 0.04^{c}	126.00 ± 2.04^{f}	-0.500 ± 0.008^{b}
Kogi State LGAs					
Ibaji	6.00 ± 0.01^{b}	0.19 ± 0.01^{b}	1.031 ± 0.01^{cd}	176.00 ± 1.01^{b}	-0.520 ± 0.003^{b}
Idah	6.15 ± 0.02^{b}	0.16 ± 0.02^{c}	1.034 ± 0.012^{c}	157.00 ± 1.02^{c}	-0.456 ± 0.003^{c}
Kabba	6.10 ± 0.00^{b}	0.18 ± 0.03^{b}	1.039 ± 0.08^{a}	138.00 ± 2.03^{d}	-0.559 ± 0.001^{a}
Lokoja	6.20 ± 0.01^{b}	0.14 ± 0.01^{d}	1.038 ± 0.07^{ab}	140.00 ± 3.01^{d}	-0.519 ± 0.007^{b}
Okene	6.08 ± 0.00^{b}	0.11 ± 0.00^{e}	1.014 ± 0.00^{f}	144.00 ± 1.00^{d}	-0.409 ± 0.005^{f}

[1] Values are the mean±Standard error, LGAs=Local Government Area
[2] Different letters of superscript along the column are significantly different P<0.05

3.3 Specific Gravity of Bovine Milk

Documented in Table 4 is SG of bovine milk which ranged from 1.026 to 1.060 g/m/s across the three states. In this present study, Niger State fresh milk had the lowest SG compared to the other states. Table 3 showed that S.G of fresh milk varied significantly among the sample from the three States. Out of 15 LGAs of the states, five LGAs milk samples did not conform to 1.027-1.035 or a mean of 1.032 g per mL set by WHO standard [21] while four LGAs had below 1.020 SG which implies addition of water. According to Abebe and Markos [22], the addition of water or other substances changes the specific gravity. Perhaps the milk vendors added to water in order to increase their profit margin. According to Zelelam and Ladin [23], a higher value of S.G 1.035 indicates skimming off fat whereas the lower value than the normal value of S.G 1.020 is indicative of water adulteration in milk. Addition of water to increase the quantity of milk lowers the milk S.G while the addition of sugar or flour/removal of butterfat increases the S.G beyond 1.035 Omore et al. [24]. Adulteration of milk by addition of water may introduce chemicals or microbial health hazards as well as reducing the nutritional and process quality and marketing value of milk. The variability of S.G (g/m/s) of milk in this present study was relatively significant with 1.030, 1.024-1.27, 1.029-1.031, 1.016 and 1.025-1.030 of previous researchers [25], Islam et al. [26], [10], [11], Teklemichael et al. [27] but in contrast with 1.040, 1.042-1.050 of Imran et al. [18] 1.040; [28] reported 1.042-1.05.

3.4 Viscosity of Bovine Milk

Fresh milk viscosity (cp) ranged from 150 to 184. Bowls of cow glasses of milk obtained from Patigi LGAs had the least viscosity 126 cp and 245 cp for fresh milk. The fresh milk sampled from Niger State were more viscous compared to the others while the milk from Kwara state was least viscous. Viscosity is a measure of the resistance of the fluid, it is the thickness or internal friction of any substance. The variation among the various milk products obtained from North Central zone in Nigeria may be attributed to the difference processing technique, cattle breed, the milk composition and lactation age. The milk from Niger state were more vicious (150-184 cp), followed by Kogi (138-176 cp) and then Kwara (123-167). At 20°C skin, milk product has the viscosity of 1.790 mPas (1.790 cp) while whole milk has 2.127 mPas (2.127 cp). The findings of this present study 126-184cp were quite higher. This may be the reflection of the milk compositions such as protein and total solids. Again Viscosity increase with total solid% and fat%, cooling milk also increase viscosity. Invariably, low viscosity implies low total solids and carbohydrates content [9], Adubofuor et al. [29]. This indicates that the fresh milk sampled from this zone had a high nutrient profile (High nutritional content). Although differences existed in viscosities of fresh milk sampled across the 3 states, their viscosity was comparable with 190.47cp for early lactating cow milk and 175.23 for late lactation milk reported by Fayeye et al. [17]. Reflecting that lactation age also affect viscosity. [30] documented that as the cattle age, a viscosity of it milk increase.

3.5 Freezing Point of Bovine Milk Table 1 shows the freezing point of milk products sampled from Niger State, Significant differences ($p<0.05$) exited among the fresh milk sampled in Niger State. The freezing point of fresh milk did not differ $P<0.05$ in Bosso and Agiae LGAs. Fresh milk sampled from Mariga had the highest FP (-0.442±0.007°C) while Edati had -0.525±0.003°C freezing point. Freezing point (FP) of milk is an important indicator of milk quality. The FP of milk is determined to prove milk adulteration with water and or to determine water added as a tool for quality indexes of purchased milk [31]. Processors use FP as a quality criterion for raw milk payment that will be received and processed in dairy products. In USA FP value greater than -0.53 closer to 0 has a lower purchasing price The statistical analysis on the Table, revealed fresh milk FP (°C) ranged from -0.442 to -0.525, -0.494 to -0.532 and -0.456 to -0.520 in Niger, Kwara, and Kogi states respectively. The European Union (EU) standard for raw milk was set to be -0.510-0.515°C, drinking milk ≤-0.520°C and ≤-0.520°C for heat treated milk Janstora et al. [32]. In Niger state and Kogi state, none the fresh milk sampled comply with the EU regulatory standard except in Kwara state (Ifelodun LGA) where fresh milk collected had FP of -0.512°C, others either have a value higher or below the set standard. The FP below or above the set standard implies the fresh milk was adulterated with water or extraneous substances. Producers have been known to add water to their milk to increase the volume of milk. When milk is diluted, the freezing points raises closer to zero. Water without solutes usually freeze at zero degrees, the presence of any solutes depresses FP below zero degrees. According to [31] one percent (1%)

of added water causes elevation of the FP of milk by -0.006°C. The FP between -0.530 and -0.534 indicate that the milk needs a checkup. FP between -0.525 to -0.529 indicates a strong probability of the presence of extraneous water. Dilution of milk with water may either be intentional or caused by technological imperfection at the primary production level. Milk water increases with grazing period of dairy, decrease in milk component and fat-free dry matter contents Sustova et al. [33], Navrátilová et al. [34]. Again, the findings of [33,34] reveal that grazing season, increase of the amount of FP (approaching zero) and supplementing of ration with sodium chloride or lack of water can reduce the amount of FP of -0.528 to -0.563 RaynaL et al.[35]. Feeding in housing period decreases the freezing point value based on increasing milk protein content Henno et al. [36]. The FP of milk varies depending on the breeds of animals and the regions. The variation observed in the FP of bovine milk across the states in this current study may be due to the nutritional, fermentation process and health status of the cow milked. High producing cows might be expected to have higher freezing points than lower producing cows. Diet, and how and when the diet was fed may be relative to collecting the milk sample, also may affect freezing point from individual cows Jonkus et al. [37]. The findings of Bjerg and Rasmussen [38] revealed that increase subclinical mastitis, dairy nutrition, water intake, nutrition of dairy cows affects FP of milk. The Freezing point decreases sharply with acidification of milk when pH decreases from 6.6 to 6.0°C, FP of -0.520°C for foremilk (colostrum milk) changes from 0.543 to 0.564°C. The accumulation of lactic acid can lead to the protein denaturation which in leads to further depression of the FP. Higher solute concentration can lead to a higher osmotic pressure, which can lower the freezing point of the milk.

4. CONCLUSION

In conclusion, there were significant variations in pH, TTA, SG, and FP of bovine milk across the three states reported in this study. SG reveals skimming off fat while the FP reflects adulteration of milk with water. Overall assessment of bovine milk across the selected states of North Central, Nigeria revealed that most of the milk sampled was not in conformity with the WHO standard hence the need for strict monitoring by the authority.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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