# INVESTIGATION OF SOME PHYSICAL PARAMETERS OF RAW BOVINE MILK SAMPLES AND COMMERCIALLY AVAILABLE EVAPORATED MILK SAMPLES

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Abstract: In this study, four physical parameters (viscosity, electrical conductivity, electric potential and pH) were determined for three milk samples obtained within Benin City. The study was conducted with the aim of establishing the interrelationship between these physical parameters of interest with change in temperature of the milk samples. Viscosity measurements were made by means of a Ubbelohde Viscometer which was made in Germany. Electrical conductivity measurements were performed by means of electrical conductivity meter (HACH, CO 150, USA), while the measurements of pH and electric potential were conducted by means of pH and Electric Potential (mV) meter (SUNTEX, SP-701, USA). The results obtained showed that the milk samples exhibited Newtonian behavior with viscosity decreasing as the temperature was increased. On the other hand, the electrical conductivity and electric potential values were observed to increase with increase in temperature as expected generally for liquids. For pH, increase in temperature resulted in decrease in pH values which is an increase in acidity. The viscosity, electrical conductivity, electric potential and pH values of the milk samples were in the range from 1.74 – 56.14 mPas, 1.31 – 6.07 mS/cm, -153– -61 mV and 6.4– 8.3, respectively. The correlation of viscosity with electrical properties was tested. The Arrhenius model was investigated to describe the temperature dependence of the viscosity of the milk samples resulting in activation energy for flow between 5.56–24.85 kJmol$^{-1}$ within the temperature range of study.

**Keywords:** Viscosity, electrical conductivity, electric potential, pH, temperature

## Introduction

As a result of the increasing nutritional demand caused by the increasing population of Nigeria, coupled with the partial ban on the importation of food into the country by the Nigerian government, the demand for food including liquid foods of high quality like milk has become a major concern to the people. There is therefore need for the food industry in Nigeria to arm itself with the essential requirements to meet up with the increasing nutritional demand of the people of Nigeria.

Food is an essential requirement for people of all ages for growth and survival. Milk is an important food which contributes immensely to the growth of humans. Milk is a white-coloured liquid food which stands as the major energy source for all infants and can be obtained as a by-product of the mammary glands of mammals. The white colour possessed by milk has a connection with the contents of fat globules and casein micelles with the characteristic property of dispersing light in the visible spectrum (Owens *et al*., 2001). Its major constituents include water, fat, protein, lactose, minerals among other constituents. It is the primary source of nutrition for young mammals or infants before they develop the ability to digest other types of food. For this reason, it is used all over the world as food for humans in one form or the other such as milk cream, butter, yogurt, ghee, sour milk, etc. As a result of its high nutritional benefit, it has been adopted as one of man's most diet items of great importance. Universally speaking, milk is known to be a complete food, endowed with the essential components for human nutrition (FOA, 2011; Teshome *et al*., 2015; Julia and Adem, 2016).

Although bovine milk was not the first to be used by man, its choice of selection is due to the fact that the milk from bovine does not only serve as a liquid food for its characteristic property of providing high amount of proteins, fats, lactose and minerals essential for human growth but also, the meat has been used by man due to its quality in preference to all other livestock used for milk. Evaporated milk is fresh milk which contains a little amount of water after being gently heated (Minim *et al*., 2002; Yohannisand Mesfin, 2015).

The electrical conductivity of a milk sample is a measure of the tendency of electric current to pass through it as a result of the presence of its soluble salt fraction (Germano *et al*., 1994). This property among other electrical properties of milk has been adopted as a means of carrying out milk quality control, as a technique of the composition monitoring of dairy products at the processing stage and as a method of checking the concentration of sweetened milk which has been condensed. It is as a matter of fact, influenced by temperature. An increase in temperature tends to cause an increase in the speed of migration of molecules of the milk sample and thereby decreasing the cohesive forces binding its molecules together.

A decrease in pH can lead to the hydrogenation of monohydrogen phosphate ions to dihydrogen phosphate ions, which may lower electrical conductivity of milk sample (Germano *et al*., 1994).

The electric potential of a sample of milk has to do with the energy which the milk sample possesses because of the charged particles contained in it such as sodium and chloride ions among other ions. Since like charges repel one another, this energy or potential difference is required to bring these like charges into the same environment where they are needed in order to counter the repulsive force set up by these like charges.

The knowledge of the physical parameters of milk samples is an important requirement for the production and assessment of high quality milk and milk products with the inclusion of infant formulas. For the purpose of assessing the quality of milk, samples of milk obtained from various super markets, unprocessed milk, milk samples from humans as well as animals from different countries like Poland, USA, Canada, Pakistan and Italy were studied extensively. For instance, Rehman and Salaria (2005) investigated the nutritional quality of some milk samples treated with ultra-heat by analysing the effect of temperature and storage time on the milk samples. From the investigation, it was found that increase in temperature as well as storage time affected the nutritional quality of the milk samples.

In Nigeria, some of the samples of milk used by the people are imported while others are produced locally. Ekpa and Onuh (2018) conducted a physicochemical study on some milk samples in Lokoja, Kogi State, for the purpose of assessing their nutritional quality to ensure that they were safe to be consumed. Some of the physicochemical parameters investigated include pH, moisture and specific gravity. Results showed that the investigated milk samples were within safe level for human consumption. However, the physicochemical properties of milk samples investigated in this study include viscosity and electrical properties such as electrical conductivity, pH and electrical potential.The viscosity measurement of milk is a technique of investigating the rheological property as well as some of the changes which occur due to the fat content of the milk sample (Mohammad *et al*., 2008)

To the best of our knowledge, not many studies have been conducted regarding the physical parameters of different samples of milk sold in Nigeria and reported. Therefore, in the present study, we investigated some physical parameters of raw bovine milk and commercially available evaporated milk samples with change in temperature.

## Materials and Methods

***Sample collection***

The raw bovine milk sample used in this study was collected from Fulani herdsmen at Aduwawa in Benin City, Edo Edo State of Nigeria, after milking directly into a container. The evaporated milk samples used in this study were peak milk and three crown milk, which were purchased from a supermarket in Benin City and distilled water which was used as control during viscosity measurements. Other materials used in this study include Viscometer (Ubbelohde Viscometer) made in Germany, pH and Electric Potential (mV) meter (SUNTEX,SP-701, USA), Electrical Conductivity meter (HACH, CO 150, USA), and a thermometer with the range (-10 – 110ºC).

***Viscosity measurements***

The viscometer was installed and used to take viscosity readings of the different milk samples at temperatures ranging from 0 – 60ºC at 10ºC interval.

***Electrical conductivity, pH and electric potential measurements***

After the installation of the conductivity meter, readings of electrical conductivity were taken at the prescribed temperatures. Similarly, readings of pH electric potential of the various milk samples were taken.

## Results and Discussion

The three samples of milk were analyzed for various properties of physicochemical origin and found that they demonstrated comparable results. The average viscosity of the samples of milk in the present study ranges from 1.74 – 56.14 mPa.s with the peak milk sample taking the lead as can be observed in Table 2. The general trend in the observed viscosity of the milk samples is seen to decrease with an increase in temperature. This behaviour of reduction in the viscosity with increase in temperature of the milk samples is expected. As a matter of fact, the dependence of viscosity of a substance upon temperature is an attribute of not only its cohesive energy but also, that of its thermal energy. The temperature dependence of viscosity for the milk samples was modeled by using the Arrhenius model (equ. 1) and the activation energy of the milk samples was estimated from the viscosity values as 5.56, 24.85 and 19.94 kJmol$^{-1}$ for bovine, peak and three crowns milk samples, respectively;

$$\eta = \eta_0 \exp\left(\frac{E_a}{RT}\right) \qquad (1)$$

**Where:** η viscosity at temperature T is, $\eta_0$ is viscosity at zero degree temperature, R is the universal gas constant, T is temperature and $E_a$is activation energy.

**Table 1: Measured viscosity values for distilled water**

| Temperature (°C) | Viscosity (mPa.s) |
|---|---|
| 0 | 1.781 ± 0.00 |
| 10 | 1.4500 ± 0.01 |
| 20 | 1.003 ± 0.01 |
| 30 | 0.837 ± 0.00 |
| 40 | 0.655 ± 0.01 |
| 50 | 0.566 ± 0.00 |
| 60 | 0.475 ± 0.01 |

**Table 2: Measured viscosity values for the milk samples**

| Temp. | Viscosity (mPa.s) | | |
|---|---|---|---|
| (ºC) | Bovine Milk | Peak Milk | Three Crowns Milk |
| 0 | 2.70 ± 0.01 | 56.14 ± 0.01 | 18.21 ± 0.01 |
| 10 | 2.23 ± 0.05 | 45.18 ± 0.01 | 16.44 ± 0.01 |
| 20 | 1.81 ± 0.01 | 38.24 ± 0.01 | 12.77 ± 0.01 |
| 30 | 1.45 ± 0.00 | 24.35 ± 0.01 | 9.38 ± 0.01 |
| 40 | 1.31 ± 0.01 | 14.27 ± 0.01 | 7.00 ± 0.00 |
| 50 | 1.94 ± 0.00 | 12.11 ± 0.01 | 5.33 ± 0.01 |
| 60 | 1.74 ± 0.01 | 8.74 ± 0.01 | 4.00 ± 0.01 |

The electrical conductivity, electric potential and pH of the milk samples ranged from 1.31 – 6.07 mS/cm; -153 – -61 mV; and 6.4 – 8.27, respectively. The relationship between the milk samples show that the bovine milk sample has the highest conductivity value than of the evaporated milk (peak milk and three crowns milk) within the temperature range of the study. The electrical conductivity of the samples of milk is due mainly to the degree of various electrolytes present in the samples. This observed variation electrical conductivity may be attributed to the different degree of the electrolytes in the samples of milk. According to Agbajor *et al.* (2017), the electrical conductivity of a sample increases with temperature. This conforms with the trend of the results in Table 3. This is also a clear indication of the bovine milk composition (Yohannisand Mesfin, 2015) which has great effect on its conductivity. Also, the acidity found in milk of natural origin is due to the contents of casein, albumin, citrates, phosphates and dioxide of carbon (Dinesh and Nrashant, 2019).

**Table 3: Measured conductivity values for the milk samples**

| Temp. | Conductivity (mScm$^{-1}$) | | |
|---|---|---|---|
| (ºC) | Bovine Milk | Peak Milk | Three Crowns Milk |
| 0 | 1.31 ± 0.00 | 2.66 ± 0.00 | 2.09 ± 0.02 |
| 10 | 1.45 ± 0.05 | 2.69 ± 0.01 | 2.23 ± 0.01 |
| 20 | 1.81 ± 0.01 | 2.96 ± 0.01 | 2.80 ± 0.00 |
| 30 | 1.94 ± 0.00 | 3.51 ± 0.01 | 3.95 ± 0.01 |
| 40 | 1.98± 0.01 | 4.72 ± 0.02 | 4.75 ± 0.00 |
| 50 | 2.23 ± 0.00 | 4.82 ± 0.03 | 4.78 ± 0.01 |
| 60 | 3.06 ± 0.00 | 6.07 ± 0.01 | 5.95 ± 0.00 |

**Table 4: Measured electric potential values for the milk samples**

| Temp. (°C) | Electric Potential (mV) | | |
|---|---|---|---|
| | **Bovine Milk** | **Peak Milk** | **Three Crowns Milk** |
| 0 | -126.00 ± 0.00 | -136.00 ± 0.00 | -153.00 ± 0.00 |
| 10 | -124.00 ± 0.00 | -134.00 ± 0.00 | -158.00 ± 0.00 |
| 20 | -120.00 ± 0.00 | -123.00 ± 0.00 | -147.00 ± 0.00 |
| 30 | -114.00 ± 0.00 | -118.00 ± 0.00 | -115.00 ± 0.00 |
| 40 | -91.00 ± 0.00 | -108.00 ± 0.00 | -106.00 ± 0.00 |
| 50 | -79.00 ± 0.00 | -103.00 ± 0.00 | -95.00 ± 0.00 |
| 60 | -61.00 ± 0.00 | -101.00 ± 0.000 | -88.00 ± 0.00 |

**Table 5: Measured pH values for the milk samples**

| Temp. (°C) | pH | | |
|---|---|---|---|
| | **Bovine Milk** | **Peak Milk** | **Three Crowns Milk** |
| 0 | 7.56 ± 0.01 | 7.89 ± 0.02 | 8.27 ± 0.04 |
| 10 | 7.51 ± 0.01 | 7.82 ± 0.03 | 8.12 ± 0.02 |
| 20 | 7.41 ± 0.00 | 7.66 ± 0.01 | 8.02 ± 0.01 |
| 30 | 7.33 ± 0.01 | 7.53 ± 0.01 | 7.49 ± 0.02 |
| 40 | 6.98 ± 0.01 | 7.38 ± 0.00 | 7.34 ± 0.03 |
| 50 | 6.81 ± 0.02 | 7.29 ± 0.01 | 7.18 ± 0.00 |
| 60 | 6.40 ± 0.01 | 7.26 ± 0.01 | 7.06 ± 0.01 |

Tables 4 and 5 clearly show the relationship between the electric potential and pH of the milk samples. As the electric potential increases, the pH decreases. It can be observed that the bovine milk is slightly acidic at higher temperatures and neutral at lower temperatures but that of the evaporated milk remains neutral at higher temperatures. However, pH range of the milk samples in this study is comparable with the pH range of 6.4 – 6.8 as reported for milk samples in previous studies (Rehman and Salaria, 2005) while the electric potential of all the milk samples are very low with negative values.

## Conclusion

The results of this study showed that the viscosity and electrical properties of bovine and evaporated milk samples gradually changed with temperature, which could be attributed to the contents of fat, protein and dry matter present in the samples of milk. Also, the milk samples were observed to exhibit Newtonian behaviour with viscosity increasing with increase in temperature.

## Conflict of Interest

Authors declare that there is no conflict of interest reported in this work.

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