Study of physical and electrical characteristics of skim milk

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ABSTRACT

The present investigation was carried out to determine the various physical and electrical characteristics of skim milk with respect to density, specific weight and electrical conductivity. These physical characteristics were determined considering three levels of temperatures 25, 30 and 35°C at intervals of 0, 1, 2 and 3 h. The highest values for density and specific weight of skim milk were observed as 1032.32 kg/m³ and 10.13 kN/m² at 25°C respectively and with respect to time it was observed 1030.99 kg/m³ and 10.12 kN/m² at 3 h respectively. The highest electrical conductivity of skim milk was 5.62 mS/cm at 35°C and with respect to time it was observed 5.54 mS/cm at 3 h. There is not much appreciable effect of variation on physical and electrical characteristics with respect to time, whereas the temperature had shown significant effect (P<0.05) on physical characteristics of skim milk. The data generated in the present investigation can be utilized as guidelines for designing of skim milk based processing systems like evaporated plant and skim milk spray drying plant etc.

Key words: Density, Electrical conductivity, Physical characteristics, Skim milk, Specific weight.

INTRODUCTION

Skim milk is a by-product obtained during the manufacture of cream. It is rich in solid-not-fat content and has high nutritional value. In dairy plants, it is mostly utilized either in standardization for the manufacture of main dairy products or preserved by removing moisture in spray dried form. Generally, skim milk consists of total solids 9.3%, comprising of protein 3.44%, lactose 5.1%, ash 0.70% and Ca 115 mg/100 g (Rattaray and Jelen, 1996).

The density of solid and liquid foods changes with temperature and pressure. Density of any food stuff is also dependent on its composition. In the literature, most of the density data is correlated empirically as a function of temperature, water, solids and fat content. The electrical properties are important when processing foods involving electric fields, electric current conduction or heating through electromagnetic waves.

These properties are also useful in the quality of foods. Electrical conductivity is a measure of how well electric current flows through a food of unit cross-sectional area, unit length, and resistance. It is the inverse value of electrical resistivity (measure of resistance to electric flow) and is expressed in SI units as Siemens/meter. Kaptan et al. (2011) reported that the electrical conductivity of milk increased with increase in temperature and increase in time. The increasing of storage of skim milk the viscosity and lactic acid content increases and the stability of skim milk slightly degraded.

MATERIALS AND METHODS

Procurement of skim milk: The skim milk was procured from Chhattisgarh State Cooperative Dairy Federation, Raipur. Skim milk was obtained as a by-product in the manufacture of cream from whole buffalo milk using centrifugal cream separator. Initially milk was collected from chilling centers at below 5°C, followed by preheating to 30-40°C then the milk was pumped to centrifugal cream separator for separating the milk into skim milk and cream. Followed by heating skim milk to 80-90°C. The heated skim milk was cooled to 5°C and was brought to College of Dairy Science and Food Technology, Raipur.

Preparation of skim milk: The skim milk (about 70 to 80 L) was procured at afternoon time and kept in refrigerated condition at 7-10°C in a refrigerator. Before the experiment, the skim milk was brought to ambient temperature. For this purpose, the skim milk, filled in milk can (40 L) was subjected to sprinkling of hot water, with little agitation inside the can. When the temperature of skim milk came to ambient condition, the basic material i.e. skim milk was ready for experimentation. The main experiment was conducted at intervals of 0, 1, 2 and 3 h after initial procedure and thus the total time taken for this experiment was 4 to 5 h. Different chemical tests such as fat, SNF and total solid contents were carried out before experiment and are presented below.

Measurement of physical characteristics of skim milk: The physical characteristics of skim milk, which were
measured, are (i) density at three levels of temperature 25, 30 and 35°C and 4 levels of time 0, 1, 2 and 3 h. The skim milk was placed in a graduated 1 litre glass beaker. Its mass was determined to calculate its density.

**Density measurement:** The physical parameter, density of skim milk was measured by using the formula

\[ \rho = \frac{\text{Mass}}{\text{Volume}} \]  

**Specific weight measurement:** The physical parameter, specific weight of skim milk was measured by using the formula

\[ \text{Specific weight} = \frac{\text{weight}}{\text{Volume}} \]  

Precisa weighing balance (XB 220A) was used for weighing of skim milk while measuring the density and specific weight, with measuring range is 0.01 mg to 220 g and deviation range is 0.0001 g to 0.001 g.

**Measurement of electrical conductivity of skim milk:** The electrical conductivity was determined using a microprocessor based conductivity/TDS meter (Model 1601, Environmental and Scientific Instruments Co, Haryana, India). The skim milk sample was placed in a 500 ml graduated glass beaker. The cell was connected to the instrument and dipped in skim milk. The temperature probe was also inserted in the sample of skim milk, which recorded the temperature of sample. The electrical conductivity of the samples was measured at three levels of temperature in range of 25, 30 and 35°C and four levels of time 0, 1, 2 and 3 h. All these methods and measurements adopted from Sahu et al. 2017.

**RESULTS AND DISCUSSION**

**Effect of time and temperature on density of skim milk:** The effect of time and temperature interval for experiment on density of skim milk (\(\rho\)) is shown in Table 2. The density of skim milk (at 25°C of fluid temperature) increased from 1031.87 kg/m³ to 1032.73 kg/m³ when time interval of experiment increased from 0 to 3 h. More or less similar trends were observed when the temperature of skim milk varied to 30 and 35°C.

### Table 2: Chemical composition of skim milk.

| Constituent      | Value (%) | Average ± S.D. |
|------------------|-----------|----------------|
| Fat              | 0.54-7    | 0.57 ± 0.1     |
| SNF              | 8.4-8.75  | 8.59 ± 0.15    |
| Total Solids     | 9.06-9.66 | 9.43 ± 0.34    |
| Titratable acidity | 0.14-0.16 | 0.15 ± 0.01    |

### Table 1: Effect of time and temperature on the density of skim milk..

| Temperature | Density of skim milk (kg/m³) | Temperature Mean |
|-------------|------------------------------|------------------|
|              | 0 h                          | 1 h              | 2 h              | 3 h              |                   |
| 25°C         | 1,031.87                     | 1,032.19         | 1,032.48         | 1,032.73         | 1,032.32          |
| 30°C         | 1,030.83                     | 1,031.03         | 1,031.31         | 1,031.55         | 1,031.18          |
| 35°C         | 1,027.92                     | 1,028.14         | 1,028.38         | 1,028.72         | 1,028.29          |
| Hour Mean    | 1,030.21                     | 1,030.46         | 1,030.73         | 1,030.99         |                   |

**T**

\[ T = \text{SE}_{\text{M}} = 0.091 \]

\[ F_{\text{cal}} = 504.503^* \]

\[ \text{Source} \]  

| Parameter | SE\text{M} | F_{\text{cal}} | Source |
|-----------|------------|----------------|--------|
| T         | 0.091      | 504.503*       | 0.262  |
| H         | 0.105      | 5.554          | 0.303  |
| T_{xh}    | 0.182      | 6.360          | 0.525  |

* = Significant (p≤0.05)

The density of skim milk has decreased significantly as the temperature of skim milk has increased at 25°C to 35°C. The decrease in density with increase in temperature might be associated with the increase in volume due to volumetric expansion. With increasing temperature decrease in viscosity is also associated with the lower cohesive forces between molecules. Sahu et al. (2017) observed that the highest value for density of paneer whey is 1015.43 kg/m³ at 20°C, they concluded that increasing density with respect to decreasing temperature.

Table 2 indicates that the mean density of skim milk was recorded to be 1032.32 kg/m³ at 25°C and decreased to 1028.29 kg/m³ at 35°C. The density of skim milk had decreased significantly as the temperature increased and this variation was significant (p≤0.05) at 25, 30 and 35°C. Similarly, while considering time interval of experiment, the density of skim milk increased slightly with increase in time and did not show significant difference.

From this analyzed data, it was recorded that the effect of temperature showed significant difference but effect of time and combined effect of temperature and time did not show significant effect on density of skim milk.

**Effect of time and temperature on specific weight of skim milk:** The effect of temperature and time interval for experiment on specific weight of skim milk is shown in Table 3. The specific weight of skim milk (at 25°C of fluid temperature) increased from 10.13 kN/m³ to 10.14 kN/m³ when time interval of experiment increased from 0 to 3 h. More or less similar trends were observed when the temperature of skim milk varied to 25 and 30°C. The decrease in specific weight with increase in temperature might be associated with increase in volume due to volumetric...
expansion, which was also due to the lower cohesive forces between molecules.

Table 3 revealed that the mean specific weight of skim milk was 10.13 kN/m$^3$ at 25$^\circ$C and decreased to 10.09 kN/m$^3$ at 35$^\circ$C. The specific weight of skim milk has decreased significantly ($p \leq 0.05$) at and above 25$^\circ$C. Similarly, while considering time interval of experiment, the specific weight of skim milk changed slightly with increase in time but does not show significant difference.

From this analyzed data, it was observed that the effect of temperature shows significant difference but the effect of time and combined effect of temperature and time did not show significant effect on specific weight of skim milk.

**Effect of time and temperature on the electrical conductivity of skim milk:**

Newer and innovative heating methods are being investigated by various research workers for exploiting their inherent advantages in dairy and food processing. The electrical conductivity of skim milk is useful when the skim milk is treated by Pulsed Electric Field (PEF), microwave heating and ohmic heating. Increase in electrical conductivity means slight reduction in milk stability because increasing of lactic acid content with increasing of storage of milk.

Table 4 showed that the electrical conductivity of skim milk (at 25$^\circ$C of fluid temperature) increased non-significantly from 5.39 mS/cm to 5.43 mS/cm as time interval of experiment increased from 0 to 3 h. It might be due to the increase in the hydrolysis of lactose in skim milk etc. Neviani et al. (1992) reported that the value of electrical conductivity of milk increased by the growth of various microorganisms and increase of acidity during the storage period of milk. Some molecules of lactose present in the skim milk might have converted into lactic acid. More or less similar trends were observed when the temperature of skim milk varied to 30 and 35$^\circ$C.

The electrical conductivity of skim milk increased significantly, as the temperature increased. The probable reason could be increase in the dissociation of electrolytes and movement of ions during electrical conductivity measurement at higher temperatures. The values obtained for electrical conductivity of skim milk in the present study were within the ranges from 5.39 mS/cm to 5.66 mS/cm. Sahu et al. (2017) observed that the highest value for electrical conductivity of paneer whey is 5.10 mS/cm at 30$^\circ$C temperature with respect to time at 3 h is 4.93 mS/cm. Mabrook and Petty (2003) concluded that electrical conductivity of skim milk (0.1% fat and 4.9% lactose) is 5.4 mS/cm. Hamana et al. (1992) reported that the average

| Temperature | Specific weight in (kN/m$^3$) | Temperature Mean |
|-------------|------------------------------|-----------------|
|             | 0 h | 1 h | 2 h | 3 h |           |
| 25$^\circ$C | 10.13 | 10.13 | 10.13 | 10.14 | 10.13 |
| 30$^\circ$C | 10.12 | 10.12 | 10.12 | 10.13 | 10.12 |
| 35$^\circ$C | 10.08 | 10.09 | 10.09 | 10.09 | 10.09 |
| Hour Mean  | 10.11 | 10.11 | 10.11 | 10.12 |

**ANOVA Table**

| Parameter | SEm | F cal |
|-----------|-----|-------|
| T         | 0.002 | 91.593* |
| H         | 0.003 | 5.061 |
| Txh       | 0.005 | 0.837 |

*- Significant ($p \leq 0.05$)
electrical conductivity of cows’ milk is in between 5.04 and 5.82 mS/cm.

Table 4 indicates that the mean electrical conductivity values of skim milk ranged from 5.41 mS/cm at 25°C to 5.62 mS/cm at 35°C. The highest and lowest values of electrical conductivity were found to be 5.62 mS/cm at 35°C and 5.41 mS/cm at 25°C and showed significant (p≤0.05) effect at each temperature.

While considering time interval of experiment, the average electrical conductivity of skim milk ranged from 5.47 mS/cm at 0 h to 5.54 mS/cm at 3 h and it was found statistically non-significant (p≥0.05). The highest and lowest values of electrical conductivity were found to be 5.52 mS/cm at 3 h and 5.47 mS/cm at 0 h.

CONCLUSION

The present investigation was carried with the objectives to have insight on variation of some physical properties of skim milk with time and temperature. The density of skim milk decreased from 1032.32 to 1028.29 kg/m$^3$ when temperature of skim milk increased from 25 to 35°C. Similarly, when time of experiment interval increased from 0 to 3 h, it increased from 1030.21 to 1030.99 kg/m$^3$. The specific weight of skim milk decreased from 10.13 to 10.09 kN/m$^3$ when temperature of skim milk increased from 25 to 35°C. Similarly, when the time interval of experiment increased from 0 to 3 h, it also increased from 10.11 kN/m$^3$ to 10.12 kN/m$^3$. The electrical conductivity of skim milk increased from 5.41 to 5.62 mS/cm when temperature of skim milk increased from 25 to 35°C. Similarly, when the time interval of experiment increased from 0 to 3 h, it also increased from 5.47 to 5.54 mS/cm.

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