PSYCHORHEOLOGICAL STUDY ON VISCOSITY OF MILK

Amol S. Vyawahare, Pratik Nawale, Sushim Kumar*, Krushna Papinwar,
Patel Dhinalkumar H. and K. Jayaraj Rao

Dairy Technology Section, National Dairy Research Institute (Southern Campus),
Adugodi, Bangalore – 560 030, India.

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ABSTRACT

Viscosity of milk with TS levels ranging from 4 – 40% was determined at 40°C by objective method using a capillary viscometer and also evaluated by subjective method. Five equations viz. linear-linear, linear-log, polynomial second order, polynomial third order and linear – exponential were fitted to the instrumental and subjective viscosities and the goodness of fit was evaluated. The results indicated that instrumental viscosity and sensory viscosities between themselves and with TS content of milk were related by polynomial second and third orders with correlation coefficient values ranging from 0.73 – 0.99. The study indicated that subjective tests also have an important role to play in determining the quality of milk.

Key words : Psychorheology, Viscosity, Milk, Correlation, Subjective evaluation

INTRODUCTION

Psychorheology is a branch of psychophysics dealing with the sensory perception of rheological properties of foods. It is also defined as the relationship between the consumer preferences and rheological properties of foods (Bourne, 2002). Psychorheology is known as a special area devoted to response of human sensory organs to various rheological properties and also their acceptance. It analyses mathematical relationship between subjective and objective rheological or textural characteristics of food products. In case of subjective analysis, the signals generated at the nerve endings of the senses are transmitted via the central nervous system to the brain where they are integrated with past experience, expectations and other conceptual factors before the opinion of the response is summarised (Amerine et al., 1965). Hence, psychorheological aspects play a vital role in consumer acceptance and product development and marketing studies. Several methods are in vogue for objective measurement of viscosity of milk – fundamental and empirical. Of these, the former methods are followed by research and academic organisations, and the latter methods are followed by the industry. Fundamental methods need to be done under controlled conditions, whereas empirical ones are carried out under convenient conditions. Ultimately, the objective of all types of analysis is to evaluate the sensory acceptance of products. In this regard, subjective methods determine the final acceptance of products and objective methods only play a supportive role. However, if one wants to study the influence of treatments on the rheological parameters of a product irrespective of sensory acceptance, then fundamental methods come in handy. Subjective evaluations also help in overcoming certain disadvantages of objective methods – the main one being wide deviations caused by the inherent variations in food products.

Viscosity of milk-an important rheological characteristic- can be determined by various objective methods and is generally expressed as centipoise or milli Pascal second (mPa.s). It can also
be expressed as low, thin, thick, flowable etc. in sensory evaluation procedures and quantified in terms of scores. The mathematical correlations would help in predicting the objective values with the help of subjective analysis results. Such correlation studies were carried out in products like chocolate milk (Hough and Sánchez, 1998), cheese (Everard et al., 2006), stirred yoghurt (Thomas et al., 2006) and tartar sauce (2006), but few were reported in other dairy products. It is a common practice for consumers to pronounce consistency of milk as thin (alluding to adulteration with water) or thick (referring to fat content). Many experienced consumers may also tell the extent of adulteration of milk with water based on the latter’s thinness or consistency. This is the result of the sensory perception recorded in the mind about the normal milk and any variation in the consistency will immediately be discerned by mind. Determining mathematical correlations between the objective and subjective data will help in predicting one value from the other.

Milk has a viscosity of 1.24 cP at 40°C (Kessler, 1981), and is highly dependent on temperature of measurement and components (Webb et al., 1974). Fat is the major contributor for viscosity of milk, hence consumers often correlate the ‘consistency’ of milk with the fat content. Quite often persons with intuitive and analytical mind will be able to say the consistency of products in terms of either acceptance or actual rheological units without the aid of any instrument. In the present study, milk viscosity was determined objectively by a bulb pipette, which is a simple capillary type tube viscometer, and the data were analysed visavis the sensory acceptance of milk’s consistency. Attempts were made to see whether viscosity of milk can be quantified by human mind with a fair degree of accuracy.

**MATERIALS AND METHODS**

**Preparation of milk with different Total Solids Levels:** Skim milk powder (380 g) (Sagar Brand) procured from local market was thoroughly mixed with 500 ml warm distilled water and the mixture filtered through muslin cloth. This milk contained 40% TS and was termed as High Total Solids Milk (HTSM). The HTSM was taken in beakers in different aliquots and diluted with distilled water progressively as shown in Table -1 to obtain milk samples of increasing TS levels. The beakers with different TS milks were kept in water bath at 40°C for tempering and then used for determination of viscosity by objective and subjective methods.

**Determination of viscosity of milk by objective method:** The viscosity of milk was determined using a 50 ml-bulb pipette adapted as a capillary viscometer, which worked based on capillary principle (Bourne, 2002). The bottom and top marks on the bulb of the pipette were marked, and distilled water was pipetted in up to the top mark and the level held with a finger. The pipette was then clamped to a stand at a fixed height. A beaker was placed beneath the pipette and the finger was removed allowing the water to flow, simultaneously stop watch (Racer Brand, 0.1 sec accuracy) was switched on. The time (sec) taken for distilled water to cross the bottom mark was recorded to the nearest 0.1 sec. Like wise, the procedure was repeated 3-4 times for all the milk samples. Average time taken was recorded for each milk sample and converted to viscosity by the following formula:

\[ n_2 = \frac{d_2 t_2}{n_1 d_1 t_1} \]

Where,
- \( d_1 \): density of water (1 g / cc)
- \( d_2 \): density of milk sample
- \( t_1 \): time taken by water in sec
- \( t_2 \): time taken by milk sample in sec
- \( n_1 \): Relative viscosity of water (1)
- \( n_2 \): Relative viscosity of milk sample (instrumental viscosity).

**Determination of viscosity and sensory acceptance of milk by subjective method:** The milk samples were evaluated by a panel of judges. Ten judges were selected from the Institute faculty and students based on their willingness, ability, experience and scientific knowledge etc (ISI,
They were acquainted with milk of varying consistency levels by serving milk with different dilutions and viscosities. The milk samples with different TS levels (4 - 40%) were tempered to 40°C and served to judges for evaluation of viscosity as well as acceptance. The sensory evaluation was carried out in Laboratory under fluorescent lamps. The judges were then asked to examine the samples carefully and record the following with reference to water: 1) viscosity of the milk samples in terms of centipoise (sensory viscosity) and 2) body and texture acceptance score on a 9-point Hedonic scale (Amerine et al., 1965). For sensory viscosity, the judges were asked to pour the milk sample from one beaker to another and critically examine the flow behaviour and consistency for estimating the viscosity. They were asked to quantify the viscosity in terms of centipoises (cP) with reference to that of water (one cP) as per perception of their mind.

**Determination of correlation among instrumental viscosity, sensory viscosity, sensory acceptance and TS%:** The objective data i.e. viscosity values determined by the capillary viscometer (termed as instrumental viscosity), and the subjective data (termed as sensory viscosity) and sensory acceptance were tabulated and correlation analysis was done between the following: Instrumental viscosity Vs Sensory viscosity, Instrumental viscosity Vs Sensory acceptance, Instrumental viscosity Vs Per cent TS and Sensory viscosity Vs Per cent TS. The paired data were fitted to the following regression equations using MS Excel programme:

i) \( y = a + bx \) (linear – linear)

ii) \( y = a + b \ln x \) (linear-log)

iii) \( y = b_0 + b_1x + b_2x^2 \) (polynomial 2nd order)

iv) \( y = b_0 + b_1x + b_2x^2 + b_3x^3 \) (polynomial 3rd order)

v) \( y = a.e^{bx} \) (linear – exponential)

Where,

\( y = \) Instrumental / Sensory viscosity  \\
\( x = \) Sensory / Instrumental viscosity/ % TS  \\
a, b_i, b_j = \) Regression coefficients

The degree of relationship was measured by coefficient of determination \( (R^2) \) values, and goodness of fit was evaluated by root mean square (RMS) values. The RMS was determined as follows (Sawhney et al., 1994):

\[
\sqrt{\frac{1}{N} \sum_{i=1}^{N} \left( \frac{W_i - W_i^*}{W_i} \right)^2} \times 100
\]

Where,

\( Wi = \) experimental observations  \\
\( W_i^* = \) calculated parameters  \\
\( N = \) number of observations.

The lower the RMS value, the better was the goodness of fit. All the mathematical calculations were carried out by computing in MS-Excel programme of MS-Office 2007 version. An RMS value of up to eight was considered as a fairly good fit (Sawhney et al., 1994).

**RESULTS AND DISCUSSION**

**Relationship between instrumental viscosity and sensory viscosity:** It is common practice in day to day life to judge the viscosity of liquids as thin, thick, flowable etc. and often relate the same to their acceptance. It suggests that there is a scope for our sensory perception to be quantified as outputs equal to those of any instruments that measure viscosity. How accurately we can predict the viscosity sensorily can be gauged by correlating the instrumental viscosity with sensory viscosity values. In Table-2, various relationships along with regression coefficients are listed. Coefficient of determination values \( (R^2) \) ranged from high (0.98) to low (0.76) and the RMS values ranged from 6.25 to 23.65. Since RMS values up to eight are considered as good fit, polynomial second order, third order and exponential relationships were found to be good for describing the relationship between instrumental and sensory viscosities. The best fit relationship is illustrated in Fig.1 along with trendline. This suggests that age-old practice of
determining the quality of milk based on ‘thickness’ of milk is not without basis. It means, to a certain extent, we can rely on our senses to gauge the viscosity of milk.

**Relationship between instrumental viscosity and sensory acceptance:** Correlation study was done to see whether we can judge acceptance of milk by viscosity determined by instrument. All the relationships studied showed medium or low correlations, indicating that it is a complex phenomenon. As the viscosity increased, the acceptance increased as indicated by increasing scores, but after a certain viscosity, the scores decreased, forming a skewed bell shaped curve (Fig.2). Bourne (2002) stated that the correlations between acceptance and objective parameters normally follow Wundt Curve, while that between intensity scale and objective analysis may follow linear or any of the four patterns reported. The curve indicated that viscosities between 1.11 and 1.24 cP are acceptable to judges as normal milk. Above these viscosities, milk was perceived as thick and was considered as not normal milk, so scored low in acceptability. Kessler (1981) also reported a viscosity value of 1.24 cP for milk at 40°C. Among the five relationships studied, the RMS values ranged from 13.51 – 18.98, the least being in the case of polynomial third order relationship (Table-2). Possibly, other models with multiple regression would have fitted better, but those were not tried in this study, because the objective of the study was to evaluate simple regression procedure rather than complex multiple regression analyses.

Viscosity is a measure of the extent to which a fluid resists flow (Walstra, 2003) and the inherent viscosity is the cumulative and combined contribution of various ingredients. Of these, fat and proteins play a major role in determining the viscosity. In case of milk, fat content controls the viscous nature and thereby profoundly influences consumer preference. At low viscosity levels, judges felt that the milk was watery, but acceptance was maximum only when the viscosity reached normal values.

**Table 1: Milk samples used in the study**

<table>
<thead>
<tr>
<th>Beaker No.</th>
<th>TS%</th>
<th>Total</th>
<th>Distilled water, g</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
<td>10</td>
<td>90</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>20</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>3</td>
<td>70</td>
</tr>
<tr>
<td>4</td>
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<td>36</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>40</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

Sensory methods may appear to lack the precision that is desirable in scientific research because of the variability from person to person, variability from hour to hour and day to day in likes and dislikes of each person. In spite of these obstacles, sensory
measurement of texture is very important aspect of food quality that cannot be ignored (Bourne, 2002).

**Relationship between instrumental viscosity and TS content:** Viscosity of milk is highly dependent on its fat and protein contents (Webb et al., 1974). The viscosity can also be correlated with total solid content, because fat and protein are the major ingredients of total solids. Relationship between fat content and viscosity of milk was reported by Van Vliet and Walstra (1979). In the present study, polynomial second order showed a fair relationship between the TS content and instrumental viscosity. The various relationships along with equation constants are shown in Table-3. The best fit relationship among those studied is shown in Fig.3 with an $R^2$ of 0.96 and RMS value of 11.12. It was observed that the viscosity of milk increased as TS increased, but not linearly. This could possibly be attributed to interaction effects among milk constituents.

**Relationship between sensory viscosity and TS content:** The relationships studied are shown in Table-3 along with $R^2$ and RMS values. It can be discerned that polynomial third order equation best described the relationship between sensory viscosity and TS content ($R^2$: 0.99, RMS: 3.88), followed by second order relationship ($R^2$: 0.99, RMS: 7.96). The almost coinciding trendline in Fig.4 demonstrates that the TS content can be predicted with a good accuracy by sensory viscosity. In other words, by experience,
persons would be able to tell the TS content of milk based on perception of mind. This further corroborates the ability of certain consumers to pass judgement on the quality of milk based on its consistency. The viscosity of a liquid or semisolid food is normally evaluated sensorily by watching the rate of flow as it pours from a container or flows across the food or the plate (Shama and Sherman, 1973). Details on studies on sensory testing of textural parameters were recorded (Szczesniak et al., 1962) and reviewed by Szczesniak (1986).

In spite of development of sophisticated instruments for measuring viscosity, sensory methods are the ultimate methods used for calibrating instruments of texture measurement, because sensory evaluation is the most important criterion for product development (Bourne, 2002). Simple instruments are industry friendly and very useful because of their empirical nature. The present study reports good correlation between the viscosity values measured by simple instrument such as bulb pipette and sensory evaluation.

### CONCLUSION

The relationship between instrumental viscosity and sensory viscosity as well as between these parameters and TS content of milk could be well described by second and third order polynomial equations ($R^2 = 0.99$) as compared to other equations ($R^2 = 0.78-0.96$). Also accuracy in terms of lower RMS value was found to be higher in second and third order polynomial equations. Hence, it was concluded that like objective tests, subjective tests also have an important role to play in determining the quality of milk.

### REFERENCES


