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CONTENTS

VIEWS

Rheological Aspects Of Khoa-Jalebi Batter

RATHOD KETAN, M[1]. PAGOTE, C.N.[1]*

[1]*Dairy Technology Section, ICAR-National Dairy Research Institute (Southern Regional Station), Adugodi, Bengaluru – 560 030.*

*** Corresponding author E-mail**: jaysharm@yahoo.com

ABSTRACT

Khoa-jalebi is one of the sweets prepared from khoa, a heat desiccated milk product. Its preparation is similar to that of the most popular variety of jalebi prepared from refined wheat flour (maida). Khoa dough is prepared by admixing khoa, arrowroot powder and Curcuma starch (toukir). The batter is then extruded through a hole in a thick cloth in the form of coiled structure and deep fried in ghee. The fried units are soaked in sugar syrup for a few minutes. The quality of the jalebi depends on the rheological quality of the batter from which it is prepared. The body and textural characteristics of batter in turn depend on its moisture content. The rheological / textural parameters of the batter have been determined using Texture Analyser and Brookfield viscometer. Based on the results obtained, it has been concluded that the batter possesses shear thinning property which helps in formation of coils of desirable size and shape.

Keywords: Rheology, khoa-jalebi, batter, viscosity, firmness, consistency

INTRODUCTION

Khoa-jalebi is one of the khoa based sweets popular in some parts of Maharashtra and Rajasthan [1]. It is made by frying the khoa based batter which is extruded from a cloth hole into hot hydrogenated vegetable oil, and soaking the fried coils in sugar syrup for sugar syrup absorption [2].

In khoa-jalebi making, proper battering is extremely important to get desirable characteristics of the final product. The moisture content of the batter is very critical as it directly affects its rheology which in turn affects the final product's quality. Further, the integrity of the batter is highly crucial for the formation of jalebi coils/ strands during subsequent frying and for maintaining the quality of finished product. Chakkaravarthi et al. [3] discussed importance of flowability and pourability of batter on the quality of maida jalebi. Rheology of batter is important not only from the point of view of acceptability of finished product's texture, but also in relation to process development, process control, quality assurance and equipment design [4]. The method of manufacture of khoa-jalebi has been standardized and reported by Pagote and Nawale [5]. For designing extrusion unit and for process mechanization, information on the rheological behaviour of jalebi batter is very important.

The objective of this work was to determine the effect of moisture level in khoa-jalebi batter on its rheological behaviour and properties. The batter rheology was studied by recording its apparent viscosity as a function of spindle RPM of rotational viscometer viz. Brookfield viscometer. Some textural parameters were also measured by Texture Analyser.

MATERIALS AND METHODS

Raw material

Fresh cow milk standardised to 3.5% fat and 8.5% SNF was taken in a steam kettle and heat desiccated to obtain khoa [6]. The khoa thus prepared for all experiments in the study, on an average contained 25.8% fat, 25.5 % lactose, 3.8% minerals, 19.4% protein and 74.4% total solids (TS). Arrowroot powder used as binder, crystal sugar used as sweetener and refined vegetable oil and hydrogenated vegetable fat used as frying medium were procured from local market sources. Starch derived from *Curcuma angustifolia*, locally known as toukir was obtained from Nagpur, Maharashtra.

Preparation of jalebi batter

The raw materials viz. fresh khoa, arrowroot powder and toukir were admixed in 100:25:5 proportion. Khoa-jalebi batter (jalebi batter) was formulated containing three different moisture levels (40, 45 and 50%) by keeping the weight of above ingredients constant and varying water levels. The weight of water to be used to get the desired moisture in the final batter was determined by Ketan and Pagote [7]:

$$x = \frac{(MQ-m)}{(1-M)}$$

Where,

M= required moisture content in the jalebi batter, %

Q= Total quantity of dry mixture of jalebi batter, gm

x = Amount of water to be added to get the required moisture content in final jalebi batter, ml

m = Moisture content in khoa, %

Measurement of rheological properties of khoa-jalebi batter

This test was carried out by back extrusion technique. The jalebi batter was filled into a 200 ml-cylindrical plastic container (up to 3/4th volume) and tempered to 30˚C. This was then placed on the platform of Texture Analyser (TA) below the TA probe which is a 40 mm plastic disc. The TA probe was brought close to the product's surface in the plastic container and the test initiated. The TA probe moved downwards to a pre-specified distance of 30 mm into the product and returned to its original position, generating a force-time curve . From the curve, the areas of the positive and negative peaks were determined as consistency (N.sec) and adhesiveness or index of viscosity (N.sec), respectively. The highest positive peak value was considered as firmness (N) and negative peak value as stickiness (N), expressed as Newton (N) [7].

Determination of apparent viscosity of khoa-jalebi batter

The apparent viscosity of khoa-jalebi batter (at about 30^{o}C) was determined by Brookfield viscometer (RVDV-II Pro, Brookfield Engineering Laboratory, USA) [7] . The jalebi batter was poured into 125 ml beaker up to 100 ml volume and a stainless steel spindle of the viscosmeter was made to rotate in the batter sample at a specified speed and depth. The torque required by the spindle was measured which was indirectly a function of viscosity of batter. Thus, the torque values and viscosity values were recorded at different speeds of the spindle starting from 10 to 100 RPM with 10 RPM increments. The range of torque measurement was kept between 10 and 100% by selection of appropriate spindle as per the nature of the khoa-jalebi batter samples. The measurement was begun with spindle rotating at a speed of 10 RPM in the batter for 30 sec. The torque and viscosity values were recorded, and then spindle RPM increased to 20 RPM. Likewise, the spindle RPM was increased to 100 RPM at 10 RPM increment levels. Each time torque and viscosity values were recorded. The type of spindle was kept the same throughout the experiments even though the torque values sometimes became higher than 100% to make the comparison easier and realistic.

Statistical analysis

The rheological data obtained from Texture Analyser and Brookfield viscometer for batter with different moisture contents was statistically analyzed by analysis of variance employing SPSS 15.0 statistical package.

RESULTS AND DISCUSSION

Effect of moisture level in batter on its rheological properties

Moisture level in batter is very important for optimum coil formation. Ketan and Pagote [7] suggested a moisture content of batter between 40 and 50% for proper coil formation. Moisture content above 50% and below 40% moisture affected coil formation during extrusion. Therefore, the rheology of batter with moisture contents of 40 – 50% was studied and results reported.

Effect of moisture level in batter on its firmness

For batters with 40, 45 and 50% moisture levels, the hardness (firmness) values were 32.24, 19.01 and 6.5 N respectively (Fig.1a). As the moisture level in batter incresed from 40 to 45 and 45 to 50%, the hardness of batter decreased from 32.24 to 19.01 and 19.01 to 6.5 N, respectively. Thus, it may be seen that there was drastic decrease in the firmness of batter from 32.24 to 6.5 N for the increase in moisture level of batter from 40 to 50%.

In batter with 40% moisture, the total solids level was higher, hence it offered more resistence to the probe during penetration resulting in higher firmness values. On the other hand, batter with 50% moisture level, contained lower solids level, hence offered less resistance to the probe during penetration resulting in lower firmness values. The firmness values of batter at different moisture levels were significantly different ($p \leq 0.05$).

Effect of moisture level in batter on its consistency

The consistency values for batter with 40, 45 and 50% moisture levels were 316.34, 179.7 and 62 N.sec, respectively (Fig.1b). It was observed that there was steep decrease in consistency values from 316.34 to 62 N.sec with increase in moisture level from 40 to 50%. Decrease in consistency was because of the change in the ratio of TS to water. For batter having 40% moisture, the TS to water ratio was more. So, the available water for dispersion of TS was less which resulted in more firmness. Hence, the consistency of batter with 40% moisture was the highest.

For batter having 45% moisture, TS to water ratio was optimum. So, more water was available for dispersion of solids. This gave homogeneous body of the batter ensuring smoother penetration of probe into the batter. In case of 50% moisture batter, the available water for dispersion of solids was much more. Hence, the resistance offered by batter to the probe was less compared to 40 and 45% moisture batters. So, the consistency value was very less for 50% moisture batter.

From the above results, it was observed that as the moisture level in jalebi batter increased, the consistency value of batter decreased. Increase in moisture level in batter improved the consistency of batter. Consistency plays the most important role in smoothness of final khoa-jalebi product. The consistency values of batter at different moisture levels were significantly different from each other ($p \leq 0.05$) (Table-1).

Effect of moisture level in batter on its index of viscosity (adhesiveness)

For batter with 40, 45 and 50% moisture levels, the viscosity index values were 48.3, 37.67 and 15.73 N.sec respectively (Fig.1c). It was observed that when moisture in batter increased from 40 to 45%, there was not much decrease in the viscosity index values i.e. 48.3 to 37.67 N.sec. But, when moisture in batter increased from 45 to 50%, there was drastic decrease in the viscosity index values from 37.67 to 15.73 N.sec.

The viscosity of batter depends on the adhesive forces present between the solids in batter. For batter with 40% moisture, water is present in smaller amount resulting in stronger adhesive forces between the particles. This resulted in more viscosity values. In batter with 50% moisture, moisture availability was more hence, weakened the adhesive forces between the particles, resulting in low viscosity of batter. Thus it was observed that as the moisture in batter increased from 40 to 45% and 45 to 50%, the viscosity index value deceased from 48.3 to 37.67 and 37.67 to 15.73 N.sec, respectively (Fig.1c).

From the above results, it was observed that with increase in moisture level in batter, the adhesiveness (index of viscosity) of batter decreased. Adhesiveness observed for batter with 50% moisture level was very less compared to batter with 40% moisture level. The adhesiveness values for batter with different moisture levels were significantly different from each other ($p \leq 0.05$) (Table-1).

Effect of moisture level in batter on its stickiness

The stickiness values of batter with 40, 45 and 50% moistures were 14.43, 9.52 and 6.45 N respectively (Fig.1d). It was observed that there was gradual decrease in the stickiness values from 14.43 to 6.45 N with increase in moisture from 40 to 50% in the batter (Fig.1d). There was decrease in stickiness of batter with increase in moisture level due to the decrease in the existing adhesive forces between solid particles. It may be understood that increase in moisture content decreases contact between solid particles, thus weakens the adhesive forces between them.

During the experiment, when probe was returning to its original position, 40% moisture batter offered more resistance, hence, more force was required to pull back the probe. In case of 50% moisture batter, less force was required by the probe to get back to its original position due to less resistance offered by the batter.

From above results, it can be concluded that increase in moisture level in batter decreased the stickiness of batter. As moisture level in batter increased from 40 to 50%, the stickiness in batter decreased. The stickiness values for batter with different moisture levels were significantly different ($p \leq 0.05$) (Table-1).

Effect of moisture level in batter on its apparent viscosity

It was observed that with increase in moisture level from 40 to 45 and 45 to 50%, the viscosity of batter decreased from 405.78 to 220.84 and 220.84 to 76.53 Pa.s, respectively (Table-2). There was drastic decrease in viscosity of batter as moisture level increased. At the same, time it was also observed that as the speed of spindle (RPM) increased, the viscosity of batter irrespective of moisture content decreased (Fig.2). Thus, the viscosity of batter could be called as apparent viscosity because the viscosity changed with the RPM of spindle employed.

For batter with 40% moisture, the viscosity value was high i.e. 405.78 Pa.s due to the higher total solids content. It had some-what semi-solid consistency and not pourable. High torque was required for shearing of the batter sample. In case of batter with 50% moisture level, the viscosity was very low i.e. 76.53 Pa.s due to less solids content. It had smooth consistency and homogeneous body. It was pourable in nature. Low torque was required for shearing of the batter sample. In case of batter with 40% moisture level, the viscosity of batter was highest. So, torque required to rotate the spindle was higher compared to rest of the two moisture levels. For the batter with 45% moisture level, the viscosity of batter was much more compared to batter with 50% moisture level. The torque value for 10 RPM speed was 55% which increased to 86% for 100 RPM speed (Table-3). The viscosity of batter decreased from 220 to 34 Pa.s. Thus, the jalebi batter showed shear thinning effect. At a given moisture content, increasing spindle speed decreased the apparent viscosity (Fig.2).

In case of batter with 50% moisture level, the batter was flowable. It had low viscosity compared to 40 and 45% moisture batter. The initial viscosity of batter was 76 Pa.s and it decreased to 15 Pa.s for the speed of 100 RPM. The statistical analysis showed that the apparent viscosity data for batter with different moisture levels were significantly different from each other ($p \leq 0.05$) (Table-2). Brookfield viscometer measures the viscosity value by measuring the torque on the spindle. The higher the torque value, the higher is the resistance the spindle undergoes from the batter sample, so the higher is the viscosity. Thus, it may be seen that the torque value was 87.11, 55.21 and 19.12%, respectively for 40, 45 and 50% moisture levels at 10 RPM spindle speed (Table-3). As spindle speed increased, torque required also increased, whereas, as moisture content in batter increased, the torque decreased. It means as moisture content increased, the resistance offered to spindle rotation also decreased, so torque decreased. This is understandable because to sustain higher speed, higher torque is required. As the speed increased from 10 to 100 RPM, the torque increased from 87.11 to 109.58% at a batter moisture content of 40%. This range for 45 and 50% batter moisture level was 55.21 to 86.46 and 19.12 to 38.36%, respectively (Table-3). In the present study, sometimes, the torque values higher than 100% were obtained. During the measurements by Brookfiled viscometer, if the displayed torque values exceed 100%, then the spindle being used needs to be replaced with another type of spindle so that torque values remain within 100% range. Alternately, spindle speed range has to be narrowed down to keep the torque values within 100%. However, in the present study, measurements were continued using only one type of spindle even if torque values exceeded 100% just for ease of comparison between the samples.

Discussion

The khoa-batter is a mixture of milk solids and starch. Arrowroot starch absorbs the water and imparts viscousness to the batter, while toukir - a Curcuma starch- helps in withholding sugar syrup in the jalebi coils. The swelling capacity of Curcuma starch is less than other starches like corn starch [8]. The particulate texture of the batter is held together by the viscous nature of arrowroot powder. Milk solids of khoa do not possess much of water holding in comparison to starch, so the batter flowability is mainly due to the arrowroot starch. So, higher the TS content or lower the moisture, higher resistance was offered to the flow, so viscosity values were higher with decreasing moisture. But as spindle speed increased, the batter was sheared and the particles bound together by the starch were broken from each other resulting in more flow. This kind of fluid flow behaviour of foodstuffs belong to shear thinning category i.e. higher the shear rate, lower is the viscosity or thinning behaviour. Thus, the khoa-batter could be classified under shear thinning category. This particular behaviour is observed in other batters also like cake batter [9] and wheat flour dough [10] [11]. Shear thinning behaviour is important in jalebi coil formation because the batter is extruded through a hole in thick cloth and force is applied for extruding it into specifically shaped coils. When pressure is applied, the batter becomes 'thin' and undergoes easy extrusion through the cloth. Without application of force, the batter does not flow out of the cloth hole. Rathod and Pagote [12] recommended a batter with moisture content of 45% for obtaining good quality khoa-jalebi.

CONCLUSION

Khoa-jalebi batter exhibited shear-thinning behaviour, a typical non-Newtonian characteristic. The analysis of variance indicated significant effect of moisture on the flow behaviour of the batter. The rheological behaviour of jalebi batter changed significantly when moisture level was increased by 5% to get the batter of 45 and 50% moisture. Thus, rheological parameters of jalebi batter can be adequately controlled by adjusting the moisture content of the batter system. From the rheological data, it could be concluded that the optimum moisture content in jalebi batter was 45% for the production of desired khoa-jalebi, as supported by Rathod and Pagote (2013).

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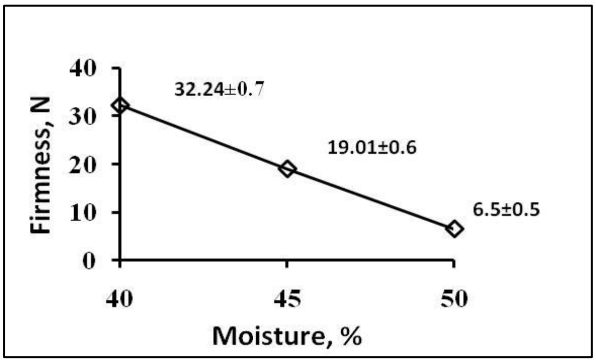

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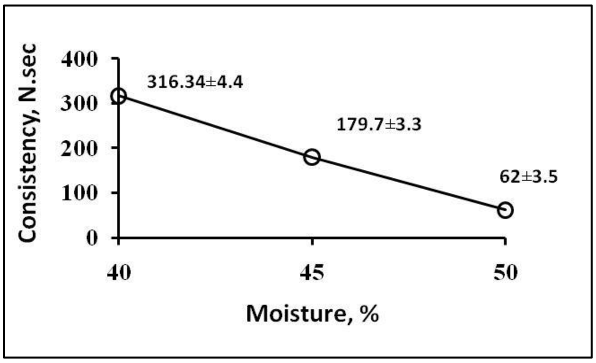

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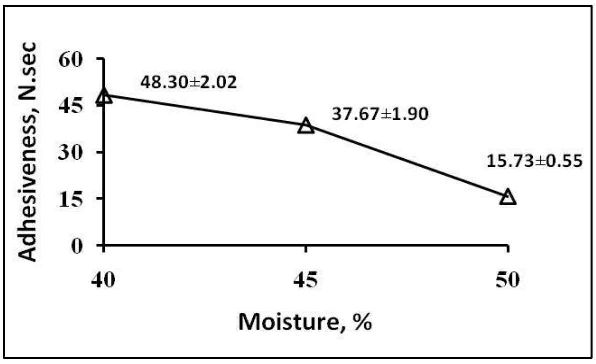

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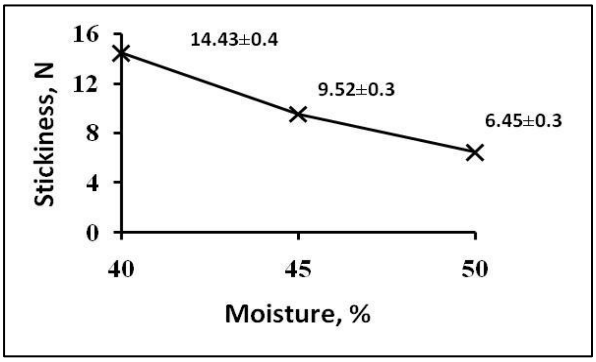

(d)

Figure 1: Textural properties of khoa-jalebi batter as influenced by moisture content

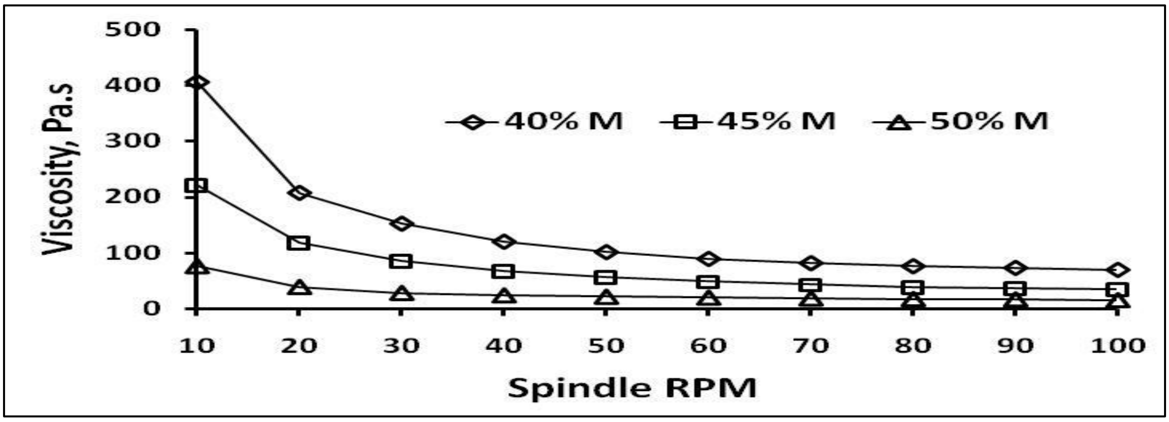

Figure 2: Decreasing viscosity of khoa-jalebi batter as a function of moisture content and spindle RPM

Table 1: ANOVA for changes in textural properties of jalebi batter containing different moisture levels

Source of variation	df	Firmness		Consistency		Adhesiveness		Stickiness	
		Mean Square	F	Mean Square	F	Mean Square	F	Mean Square	F
Between Moisture levels	2	3312.0	8862.1	358614.4	5206.5	5518.0	570.5	162.0	2493.3
Error	57	0.374	-	68.9	-	9.672	-	0.065	-
Total	59	-	-	-	-	-	-	-	-

Table 2:Apparent viscosity of jalebi batter containing different moisture levels and ANOVA

Moisture levels in batter, %	Apparent viscosity, Pa.sec*	ANOVA				
		Source of variation	**Sum of squares**	**df**	**Mean square**	**F**
40	405.78±6.0	Between moisture levels	550565.6	2	275282.8	16057.8
45	220.84±7	Error	462.9	27	17.1	-
50	76.53±6	Total	551028.4	29	-	-

* Spindle RPM 10

Table 3: Torque values on Brookfield viscometer spindle rotating at various RPM in jalebi batter with different moisture levels

Spindle speed, RPM	Average torque, %		
	40% M	**45% M**	**50% M**
10	87.11	55.21	19.12
20	91.89	58.87	19.54
30	94.71	64.08	21.31
40	97.03	67.5	23.99
50	99.20	70.75	27.11
60	101.44	72.6	29.84
70	103.67	74.93	32.29
80	106.06	78.16	34.63
90	107.91	82.28	36.75
100	109.58	86.46	38.36

Note: The torque values higher than 100% obtained because of use of same spindle for comparison purposes