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Characteristics of Chickpea Flour Batter for Boondi Preparation

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Abstract

The study was undertaken to determine the parameters of chickpea batter for boondi laddu prepared with four different flour particle sizes (137.5, 165, 196, and 231 µm) and six water to batter percentages (45.0, 47.5, 50.0, 52.5, 55.0, and 57.5). Stress-strain relationships for the batters were determined using Anton Paar Rheometer with cone and plate probe. Analysis of the data using rheoplus software yielded the values of Apparent Viscosity, Yield Stress, Consistency Index, and Flow Behavior Index. Boondi of about 3 mm diameter was prepared from these batters and deep fried at 180 ± 3°C, for 90s. Shericity and color of boondi were quantified to select the batter composition and rheological parameters. The chickpea batter is essentially a pseudoplastic fluid except the batter being dilatant at 231 µm particle size prepared with 55 and 57.5% water to batter percentage. Herschel Bulkley model represented the rheological data closely (r^2 > 0.95). Boondi sphericity and color permitted the selection of most appropriate batter composition (165 µm flour particle size and 55% water to batter percentage), where the apparent viscosity was 0.82 Pa.s, yield stress as 5.32 Pa, consistency index as 1.45 Pa.s^n , and flow behavior index as 0.87. Thus, the study resulted into the determination of the composition for the preparation of chickpea flour batter and it's rheological parameters which would yield appropriate quality boondi for laddu.

Keywords: *Batter Rheology; Pseudoplastic Fluids; Rheometer; Sphericity; Frying Temperature*

Introduction

There is at present an increased consumer preference for nutritious and safe food products at affordable price. Ethnic foods are there world over that are nutritious and tasty. These ethnic foods could be standardized to meet the nutritional needs of consumers globally provided such foods possess superior quality and safety. Laddu in India is one such snack/dessert food [1] and could also have reference to medicinal or non-food preparations [2]. When laddu is composed of boondi, it is known as boondi laddu . Boondi is a Hindi word meaning like liquid drop, i.e. 'boond'-like. Thus, a boondi laddu is a lump of solidified drops of food shaped as a ball. Like a cell in a living creature, a boondi (1 mm to 10 mm diameter) represents the composition of laddu (30 mm to 150 mm). Boondi laddus are ubiquitous in India and many other parts of the world. Boondi laddus are nutritious, tasty, and storable for several weeks [3]. The effort is to standardize the composition of this traditional Indian traditional dish and to develop technology for its mass production so that the same quality product could be made available globally.

Laddu comes from a Sanskrit word transliterated as ladduka or lattika meaning "ball". Boondi laddus are made of chickpea flour based boondi, ghee/butter/oil and sugar with other ingredients that vary by recipe, like chopped nuts or dried raisins, and often served on festive or religious occasions [4]. The history of laddu in India is several centuries or millennia, and is logical to expect a large variation in the composition and method of preparation depending upon the geographical region, available ingredients, and cultural backgrounds. There is a belief that laddu provided an easy method of administering medicines in ancient times and the type of medical treatment decided the composition of laddu. Tirupati boondi laddu [5] has recently completed 300 years of its existence and acquired GI status due to its uniqueness of location and composition [6].

Boondi for boondi laddu is made from chickpea (*Cicerarietinum*) which is one of the top five legumes grown as a staple food crop in tropical and sub-tropical Asia [7] and is being used for making a number of traditional food products at industrial and household levels. A preparation of good quality boondi is a pre-requisite for the production of high quality boondi laddu, and the success of boondi preparation for laddu depends on the flow behavior or rheology of batter which can be studied by recording their responses to shear rate. The study of rheology of chickpea batter is not only essential for achieving superior quality of final product as to color and shape of boondi but also for development and control of process, quality assurance and design of handling and processing equipment.

Chickpeas (*Cicerarietinum* L.) are of two types (kabuli and desi). Desi chickpeas are small and have dark seed coat and a yellow interior; and kabuli chickpeas are larger with a thinner seed coat and beige-colored cotyledons. Desi chickpeas are called chana or Bengal gram, and have generally been used for boondi laddu although there is no stated reason as to why the other types of chickpea or other legumes could not be used for boondi laddu. Chickpea of desi variety contains about 61.0% carbohydrate, 17.0 - 22.0% protein, 3.0 - 7.0% fat, and 18.0 - 22.0% total digestible fibre [8].

Although boondi laddus have been made for a very long time, efforts have been made only during the past three decades or so to understand the science of boondi laddu and to develop appropriate technology. The objective of this study was to determine the parameters of chickpea batter for preparation of boondi laddu prepared with four different flour particle sizes (137.5, 165, 196, and 231 μm) and six water to batter percentages (45.0, 47.5, 50.0, 52.5, 55.0, and 57.5).

Materials and Methods

The boondi laddu preparation begins by selecting the right variety of chickpea and drying it to the desirable moisture content before milling it into flour having desirable particle size distribution. Batter is prepared by adding water and stirring it so that the mixture is smooth and has the right rheology. Sugar syrup is prepared having the right consistency, and vegetable oil or ghee is heated to about 180°C in a concave steel pan (wok) and boondi is prepared from the batter by pouring it through a perforated ladle directly into the heated fat and is fried. The prepaid boondi is soaked in the sugar syrup. The boondi keeps getting added till all the syrup has been absorbed and it does not drip when a small quantity of sweetened boondi is held in hand and squeezed lightly. Laddus are shaped by slightly compressing the sweetened boondi in ball shape such that the mass does not crumble when the compressive force is released.

Tirupati laddu preparation is a five step process [9]. Besides the main ingredients, cardamom powder, saffron strands, cashews, grape raisins, almonds can be added. The process begins with grinding the Bengal gram cotyledons into flour. The ground flour is then made into a thick paste by mixing it with water. Requisite pure cow ghee is heated in a kadai to about 80°C. The thick paste is taken in a ladle and poured over a multi holed tawa, and spread. During the spreading the paste passes through the holes in the tawa which is held just above the kadai containing boiling oil so that the paste passing through the hole falls into the boiling oil and gets fried. The boondis are fried till acquiring yellow color. Sugar syrup is made by mixing sugar with water (1: 1 ratio), and the solution is heated to a temperature of above 100°C till the concentration attained is 75 brix. Then the solution is allowed to cool and the resultant mixture is called sugar syrup. Additives like cashew nuts and almonds are fried in pure cow ghee. The boondi, sugar syrup, nuts, raisins, cardamom and sugar candy are mixed together, and manually moulded into the round shape of the laddu, which is the end/finished product.

The above mentioned two processes may differ in terms of batter composition, boondi preparation, sugar syrup, and the formation of laddus. The end product is a ball shaped lump of sweetened boondi with added to make them special.

Ingredients

Cleaned and dehusked desi chickpea was procured in one lot to obviate the variability. The chickpeas were dried to 7% (wb) before milling. Commercially available vegetable oil (Soybean oil) was used for Boondi frying. In the sieve analysis, the particle size of the flour retained on a particular sieve was taken to be of the average of the sizes of the sieve through which the flour passed and the sieve on which it was retained. Four particle sizes (231, 196, 165, and 137.5 μm) were obtained on the basis of the chickpea flour used by commercial laddu manufacturers. Amount of water used to prepare the batter was represented as the water to batter percentage (w/w), and six levels of the percentages selected for the study (45, 47.5, 50, 52.5, 55, and 57.5%).

Preparation of batter

Measured amount of flour of a selected particle size was taken in a 100 ml beaker. Required quantity of water was added to make 45%, 47.5%, 50%, 52.5%, 55% and 57.5% (water to batter percentage on w/w basis).

For rheology tests the quantity of the flour taken was 10 g/sample whereas it was 25 g/sample for preparation of Boondi. To obtain a lump free and smooth batter, measured amount of water was added slowly to the flour while continuously stirring with a glass rod for 2 minutes.

Rheological measurements

The study was carried out at a constant temperature of 20 ± 1°C and shear rate was increased progressively from 3 to 1400 s^{-1} to obtain 100 data points. All the rheological measurements were made in triplicate and the batter was prepared separately for each test.

The shear rate and shear stress data obtained from the rheometer was used to obtain the values of apparent viscosity, flow behavior index, consistency index and yield stress.

Preparation of Boondi

The oil was heated to a temperature of 180 ± 3°C, and the batter was poured into the oil through a perforated ladle (3 mm perforations) moving with a vertical reciprocating jerk over 8.0 cm height. The action of the ladle caused batter to split into batter drops, called boondi. Boondi was fried for 90s and was packed in air tight packages and stored in desiccators for further analysis.

Equipment

A batch type tray dryer was used for drying of dehusked chick pea to bring the initial moisture content to 13% (wb). The temperature of the air in the tray drier is maintained by a thermostat in the range of 40 to 100°C. The hot air flows from bottom of the drying chamber, dries the material on the trays and leaves the chamber through the vent at the top.

The chickpea samples at 7% mc (wb) were ground in a hammer mill. After grinding, the fine particles pass through the perforated screen at the discharge while the coarse particles remain within the milling chamber for further size reduction. Output product particle size can be changed by altering screen size, speed of rotation of shaft and hammer configuration. For obtaining very fine end product, speed of rotation of shaft should be high, size of screen should be small and number of hammers should be large. For separating the chick pea flour obtained from the hammer mill into different particle sizes, 250 gram of flour was placed on the top sieve of the shaker and operated for two hours. The sieves used were 250, 212, 180, 150, 125 and 75 μm and the flour retained on each sieve was packed in polyethylene bags. A Mitutoya Micrometer with measurement range of 0 to 25mm and least count of 0.001mm was used for measuring the size of Boondi.

Anton Paar Rheometer with Rheoplus software was used for studying the rheology of the batter samples.. Cone and plate probe was used for the measurements in the study. Konika Minolta-Chroma meter (model CR-400) was used for color measurement. Color is measured in terms of values of L*, a* and b* . Positive values of L* represent brighter color and negative values darker color, a* with positive sign indicates red and negative sign green, and b* values with positive sign indicate yellow and negative sign blue. In case of Boondi, preferably, L* values should be high in positive direction, a* values should be lower with positive sign and b* values should be high with positive sign for obtaining boondi of bright yellowish color.

The stress-strain data so obtained was then fitted to different selected rheological models to determine the goodness of fit.

Theoretical considerations

The flow behavior of batter could be represented using an appropriate shear stress vs strain relationship [10]. The variation in the composition of the batter would affect the rheological behavior ranging from Newtonian to non-Newtonian. Most liquids which have more than 90% water like coffee, fruit juices, milk follow Newtonian behavior. According to Newton's Law of viscosity:

$$\tau = \mu\gamma \quad (1)$$

Where, τ = shear stress (N/m^2)

μ = viscosity (Pa.s)

γ = shear rate (1/s)

Since the chickpea flour batter has much lower water content as compared to Newtonian fluids, the batter would more likely be a non-Newtonian fluid. These foods may be shear thinning or shear thickening and follow either Ostwald-De Waele or power law models.

$$\tau = k.\gamma^n \quad (2)$$

Where, k = consistency index ($Pa.s^n$)

n = flow behavior index

Flow behavior index is less than 1 for shear thinning/pseudo-plastic foods and greater than 1 for shear thickening foods. Apparent viscosity decreases when shear rate is increased for shear thinning fluids. This is due to straightening of molecules in food and aligning them in direction of flow, decreasing the resistance to flow. Purees and concentrated fruit juices are the examples of shear thinning fluids. However, if the apparent viscosity increases when the shear rate increases, the fluids are known as shear thickening fluids. Examples for this type of foods are corn and waxy starches. Shear thickening fluids are also known as dilatant fluids, where there is an increase in viscosity along with increase in volume.

Bingham foods are essentially Newtonian foods except that the shear stress applied is greater than yield stress. At shear stress lower than yield stress these foods remain rigid. Yield stress is the minimum stress at which the material begins to flow. Some examples for this type of foods are tomato paste, mayonnaise and ketchup.

$\tau = k.\gamma$ (3)

Where, τ_0 is the Yield stress in Pa. Non-Bingham foods are those that act as shear thickening or shear thinning once the shear stress exceeds the yield stress. These foods follow Herschel-Bulkley model which is an addition of yield stress to the power law equation.

$\tau = \tau 0 + k.\gamma^n$ (4)

Examples of this type of foods are raisin paste, fish paste, flour batters.

Sphericity

Three dimensions namely length, breadth and thickness are measured and the value is calculated as follows.

$$\text{Sphericity} = \frac{(\text{Length x Breadth x Thickness})^{1/3}}{\text{Length}} \quad (5)$$

The value of sphericity lies between 0 and 1. Perfect sphere shape objects have sphericity of 1 and irregular bodies have less than 1.

Results and Discussion

Shear stress-shear strain relationships

All the curves are non-linear, concave downward to the shear rate axis, indicating that the chick pea flour batter is non-Newtonian and shear thinning fluid (Figure 1). This result is in agreement with that of Bhattacharya., *et al* [11]. Concluded that the Bengal gram flour batters were pseudo-plastic and exhibited yield stress. The shear rate-shear stress data followed the Herschel-Bulkley model closely. Chhinnan., *et al*. [12] had observed that power law model described adequately the flow behavior of cowpea pastes. Mukprasirt., *et al*. [13] found Herschel-Bulkley model to be the best fit for all rice flour based batters formulated with different ratios of rice to corn flour, oxidized corn starch, and methylcellulose. Wang., *et al*. [14] observed that even the cooked pastes of rice flour were shear-thinning in nature. Therefore, the shear stress - shear strain relationship observed in the present study is in conformity with those of earlier investigators. At any particular water to batter percentage, say 50%, batter with coarser particles had higher shear stress values than sample with finer particles at a given shear rate, and this trend was observed at all water to batter percentages.

The curves are non-linear at all water contents, indicating the non-Newtonian behavior. The four rheological parameters, i.e. apparent viscosity, consistency index, flow behavior index and yield stress were obtained from the experimental data.

Apparent Viscosity

Apparent viscosity at shear rate of 100s for the chickpea flour batter samples (Table 1) ranged between 0.39 and 15.53 Pa.s (390 to 15530 cp). Some of the fluids that have viscosities in this range are citrus fruit pulp, beet sauce, glycerin, and honey. For any particle size, apparent viscosity decreases when there is an increase in water content in the batter, suggesting that alignment of particles at high water content, reduced the resistance between the particles to flow. As the solid concentration in batter increased, the flow experienced greater resistance and, hence, higher apparent viscosity.

At any selected water to flour percentage, the apparent viscosity increased with increase in particle size. The absolute difference between apparent viscosities of samples with 137.5 μm and 231 μm is high when less (45%) water is added to the sample, because high solid contents requiring higher torque for shearing the samples with coarser particles. But at 57.50% the absolute variation in apparent viscosities between different particle sizes is low as the samples become pourable. The variation in apparent viscosities of chickpea flour batter with respect to particle and water to batter percentage is similar to the results published by Bhattacharya., et al. [11] as well as Ravi and Bhattacharya [15]. Look at the values in table 1 for particle size of 196 μm and 50% water to batter percentage indicates the apparent viscosity value slightly lower than the values for 165 and 231 μm. This appears to be due to experimental error as indicated by the standard deviations for the mean values.

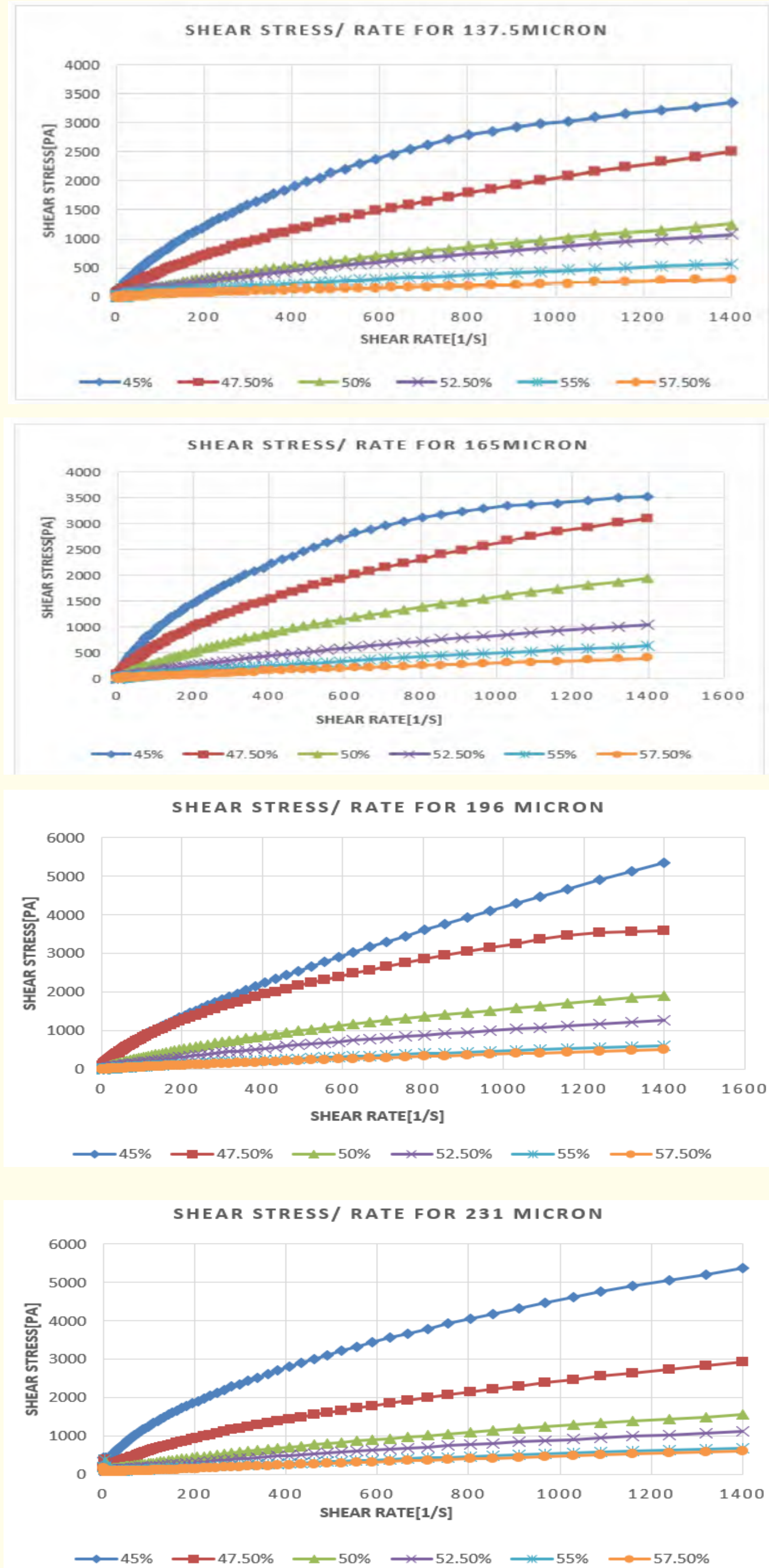

Figure 1: *Shear stress- Shear rate curves for particle size 137.5, 165, 196 and 231 μm at different Water to batter percentages.*

Water to batter (%)	Mean Particle size (μm)			
	137.5	165	196	231
45	7.82 ± 0.43	9.78 ± 0.94	12.43 ± 0.73	15.53 ± 2.48
47.5	4.37 ± 0.46	5.56 ± 0.21	5.88 ± 0.06	6.17 ± 0.23
50	1.80 ± 0.41	3.00 ± 0.29	2.89 ± 0.13	3.04 ± 0.31
52.5	1.46 ± 0.28	1.49 ± 0.01	1.92 ± 0.06	1.95 ± 0.21
55	0.79 ± 0.03	0.82 ± 0.01	0.86 ± 0.05	1.32 ± 0.08
57.5	0.39 ± 0.0	0.47 ± 0.02	0.64 ± 0.02	1.13 ± 0.07

Table 1: *Mean and standard deviation of apparent viscosity (Pa.s) of chickpea flour batter at shear rate of 100 $s^{-1.}$*

Consistency index (Pa.s^n)

Consistency index varied between 0.06 and 85.34 Pa.s^n (Table 2). At any particular flour particle size, the consistency index decreased as the water to batter percentage increased from 45 to 57.5%. When smaller amount of water (45%) is added, the ratio of total solids to water is high, devoid a more resistance to flow. Wang., *et al.* [14] observed that consistency index for rice flour pastes increased with increasing flour concentration. Bhattacharya and Bhattacharya [16] for cooked maize flour suspension also reported increasing trend of consistency index with flour concentration It is observed that at 45% water to batter percentage, the variation in consistency index between samples of 137.5 and 231 μm particle sizes is very high. Consistency index at 45%, is much smaller for the sample with 137.5 μm particle size as compared to the sample with 231μm particles, because the smaller particles can easily disperse in available water. However, the variation in consistency indices for 57.5% water to batter percentage is much smaller. Another important observation relates to a very low value of consistency index (0.06 Pa.sn) for the batter prepared with 231 μm particle size and 57.5% water to batter percentage. It would become clear later in the section on flow behavior index that the batters prepared with the flour of particle size 231 μm and water to batter percentage values of 55% and 57.5 exhibited shear thickening fluid characteristics. Thus, the low value of consistency index could be due to the change in the nature of the non-newtonian batter from shear thinning to shear thickening fluid. Literature search indicated that the characteristics of chickpea flour batter of large particle size of 231 μm had not been reported earlier.

Water to batter (%)	Mean Particle size (μm)			
	137.5	165	196	231
45	26.69 ± 3.56	35.06 ± 9.36	45.57 ± 5.44	85.34 ± 24.19
47.5	11.33 ± 1.87	15.51 ± 1.45	16.96 ± 0.59	14.98 ± 4.27
50	3.34 ± 0.84	5.45 ± 1.02	6.49 ± 0.69	5.31 ± 0.22
52.5	3.01 ± 0.76	2.54 ± 0.07	3.67 ± 0.12	3.85 ± 1.31
55	1.67 ± 0.12	1.45 ± 0.2	1.33 ± 0.12	0.56 ± 0.23
57.5	0.70 ± 0.07	1.08 ± 0.12	1.32 ± 0.18	0.06 ± 0.07

Table 2: *Mean and standard deviation of Consistency index (Pa.s^n) of chickpea flour batter at shear rate of 100 s^{-1}.*

Yield stress

Yield stress values of chickpea batter samples ranged between 2.79 Pa and 108.27 Pa (Table 3). At all the particle sizes, increase in water to batter percentage decreased the yield stress. The batter becomes easily pourable at higher water content levels, requiring lower force to initiate the flow. When particle size is small, dispersion of flour particles in the added water is easier, lowering the resistance to flow. For the samples with 231μm particle size, the magnitude of yield stress at all moisture levels is very high when comparing with other particle sizes. Bhattacharya., *et al.* [11] reported the yield stress values between 0.24 and 14.78 Pa. for concentrations up to 45%. The present study, however, goes beyond their concentration range; 45% concentration corresponds to 55% water to batter percentage. Thus, the present study has included much more concentrated batters and, hence the wider range of yield stresses observed. The yield stress values observed for the batters corresponding to the flour particle size of 231 μm are relatively larger than those for other batters. Since the batters of flour particle size 231 μm had earlier not been studied, the yield stress values for this set of batters could not be compared with any of the previous studies.

Water to batter (%)	Mean Particle size (μm)			
	137.5	165	196	231
45	18.62 ± 8.88	21.23 ± 5.15	34.00 ± 1.48	87.40 ± 6.01
47.5	10.47 ± 0.29	17.67 ± 2.95	26.42 ± 0.70	106.87 ± 15.95
50	10.80 ± 1.34	13.93 ± 0.31	10.76 ± 0.94	101.90 ± 4.46
52.5	8.64 ± 0.88	8.38 ± 0.26	10.45 ± 2.19	108.27 ± 11.84
55	6.90 ± 0.3	5.32 ± 0.57	9.43 ± 0.97	94.57 ± 13.04
57.5	2.59 ± 0.17	3.03 ± 0.42	4.19 ± 0.44	80.47 ± 5.19

Table 3: *Mean and standard deviation of Yield stress (Pa) of chickpea flour batter at shear rate of 100 s^{-1}.*

Flow behavior index

For any particle size, increase in water to batter percentage increase the flow behavior index value, the increase being the steepest in case of 231 micron size flour (Table 4). At 231 μm particle size, when water to flour percentage is 55 and 57.5%, the samples behave like shear thickening fluids (flow behavior index is greater than 1). None of the previous studies on chickpea flour batter had extended their experimental particle size range up to 231 μm. Therefore, there is no previous reference to the chickpea flour batter turning from shear thinning fluid to shear thickening fluid when chickpea flour particle size increased to 231 μm. For the remaining set of batters, the flow behavior indices are generally in the same range as that observed by Bhattacharya., *et al* [11].

Effect of particle size and water to batter percentage on color of boondi

The experimental data from the present study, therefore, confirm that the chickpea flour batters for the range of flour particle sizes and the water to batter percentages exhibit non-Newtonian behavior and that Hershel Bulkley model closely represented the shear stress-strain data. The experimental analysis further indicates that while the batters were generally shear-thinning fluids, they could become shear thickening fluids if the flour particle size increased beyond 231 μm.

Water to batter (%)	Mean Particle size (μm)			
	137.5	165	196	231
45	0.74 ± 0.02	0.72 ± 0.04	0.71 ± 0.03	0.62 ± 0.02
47.5	0.82 ± 0.01	0.75 ± 0.02	0.76 ± 0.01	0.77 ± 0.05
50	0.85 ± 0.01	0.85 ± 0.00	0.82 ± 0.01	0.79 ± 0.02
52.5	0.83 ± 0.01	0.87 ± 0.01	0.84 ± 0.01	0.91 ± 0.13
55	0.81 ± 0.01	0.87 ± 0.03	0.87 ± 0.01	1.27 ± 0.23
57.5	0.85 ± 0.02	0.81 ± 0.03	0.83 ± 0.02	1.54 ± 0.24

Table 4: *Flow Behavior Index of Chick pea flour batter at shear rate of 100 s^{-1}.*

Color measurements of the fried boondi were made three times for a sample and the mean values were calculated. The color values of boondi samples at different compositions are as follows.

L* values of Boondi

The effect of water to batter percentage on brightness of fried boondi is clearer whereas there is no clear trend in effect of particle size on brightness, L*, of boondi. There is an increasing trend in L* values of boondi prepared with 50 to 55% water content. The whiteness values are the highest for the water to batter percentages of 55 and 57.5% irrespective of the flour particle size (Table 5).

Mean of Chroma values												
Water %	137.5 μm			165 μm			196 μm			231 μm		
	L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
50	53.93 ± 1.15	5.71 ± 1.24	16.00 ± 2.17	56.41 ± 0.06	3.89 ± 0.35	21.1 ± 2.66	51.42 ± 3.50	7.45 ± 1.35	15.94 ± 2.50	50.93 ± 0.97	6.85 ± 0.88	16.46 ± 1.84
52.5	53.88 ± 0.57	5.31 ± 0.64	17.54 ± 2.02	56.94 ± 0.33	3.14 ± 0.64	20.51 ± 2.07	56.14 ± 1.78	3.58 ± 1.04	18.04 ± 1.78	52.66 ± 5.08	4.21 ± 1.20	17.62 ± 4.30
55	63.09 ± 1.69	0.2 ± 0.51	20.74 ± 0.42	61.76 ± 1.34	0.42 ± 0.64	24.37 ± 1.29	60.7 ± 2.81	2.7 ± 1.31	23.76 ± 1.92	62.04 ± 3.90	0.15 ± 0.43	22.88 ± 1.94
57.5	61.69 ± 1.12	0.28 ± 0.25	21.58 ± 2.16	62.57 ± 1.98	-0.28 ± 0.59	22.45 ± 1.15	62.21 ± 1.59	0.53 ± 0.46	25.31 ± 1.22	58.79 ± 2.19	1.74 ± 0.27	21.86 ± 0.99

Table 5: *Mean and standard deviation of Chroma Values for fried boondi.*

a* values of Boondi

The a* values decreased as the water to batter percentage increased from 50 to 55% (Table 5). At 57.5%, change in color of boondi to dark red is observed in samples with particle sizes 137.5 μm and 231μm. on a* values.

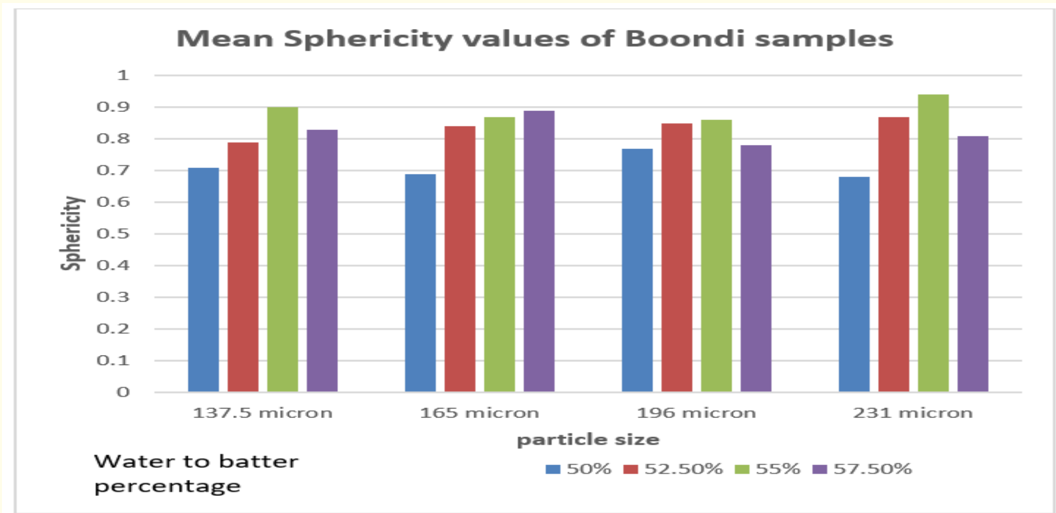

Figure 2: *Sphericity of different boondi samples.*

b* values of Boondi

For All particle sizes increase in water percentage up to 55% increased the yellowness of boondi (Table 5). Above 55% of water to batter percentage, the yellowness of samples with particle sizes of 165 and 231µm decreased . Samples with particle size 165 µm, as compared to the other flour particle sizes, have the maximum yellow color at all water to flour percentages.

Ravi and Susheelamma [17] measured the color of boondi using a Shimadzu (M/S Shimadzu Corp., Kyoto, Japan) model MPC-3100 color measuring instrument by reflectance with an integrating spheroid (Hunter 1975). They reported the 'L' values ranging from 29.75 to 61.75, all positive 'a' values, and large positive 'b' values. Chethana [18] reported the values of L*, a* and b* as 45.16 ± 0.78, 7.62 ± 0.12, and 40.47 ± 0.33, respectively, for boondi laddu one day after the preparation. The values obtained in the present study, i.e. L* between 50.73 - 63.09, a* between 0.15 - 7.45 and b* between 15.94 - 25.31 compare very well with those of Ravi and Susheelamma [17] and Chethana [18].

Effect of particle size and water to batter percentage on shape of boondi

Boondi samples have higher sphericity values at water to batter percentage of 55 (Figure 2). There is, in general, an increase in sphericity of boondi with addition of water up to 55% and subsequently the sphericity values decrease. Thus, the optimum level of water to batter percentage should be 55 for getting spherical shaped boondi. There is no clear influence of particle size of flour on sphericity of boondi.

The color comparisons indicate that the boondi prepared with flour particle size of 165 micron and 55% water to flour percentage had the best color, i.e. bright yellow color. Therefore, boondi prepared with the batter from chickpea flour of 165 micron particles and 55% water to batter percentage is the best in terms of sphericity and color.

Murthy., *et al.* [19] concluded that 52 - 54% water to batter resulted into superior quality boondi of about 3 mm diameter. Ravi and Susheelamma [17] concluded that the optimum water to battle percentage was 59.6% for 2 mm boondi.

Conclusion

The study was carried out for determining appropriate water to flour ratio and particle size of chickpea flour for preparation of 3 mm diameter boondi of uniform shape and color. The range of variables included four different flour particle sizes (137.5, 165, 196, and 231 µm) and six water to batter percentages (45.0, 47.5, 50.0, 52.5, 55.0, and 57.5%). All the chickpea batters in this study exhibited pseudo-plastic behavior except for those prepared with 231 micron flour particle size and water to batter percentages of 55% and 57.5% where the behavior was that of a shear thickening fluid. Herschel Bulkey model was found to fit the shear stress-shear rate data (r^2 values greater than 0.98) and the values of the apparent viscosity, yield stress, consistency index and flow behavior index were obtained as 0.39 to 15.53 Pa.s, 2.79 to 108.27 Pa, 0.06 to 85.34 Pa.sn and 0.62 to 1.54 respectively, for all the combinations of parameters in this study.

Boondi was prepared with different batter combinations using the same frying conditions, i.e. frying fat temperature 180 ± 3°C, frying time 90s, opening size in ladle 3 mm and height of boondi drop 8 cm. Shape (sphericity) and color of the resultant boondi were quantified. The results indicate that spherical boondi of bright yellow color and 3 mm size could be successfully prepared from chickpea flour of 165 micron particle size and 55% water to batter percentage.

Bibliography

1. Sinha AK. "Anthropology of sweetmeats". Gyan Publishing House, Ansal building commercial complex, New Delhi, India (2000): 299.
2. Pasupuleti S., *et al*. "An experimental study to evaluate the effectiveness of Krishna poshak mix on nutritional status of rural anganawadi children of Pedaparimi village, Mangalgiri Mandalam, Guntur district, Andhra Pradesh". *Asian Journal of Nursing Education and Research* 7.3 (2017): 407-412.
3. Semwal AD., *et al*. "Keeping quality of fried sweet boondi". *Journal of Food Science and Technology* 42.3 (2005): 285-287.
4. Dahiya A. "Foods of Haryana: The Great Desserts". Published by IHTM-MDU in association with Intellectual Foundation of India (2013): 52.
5. Thimmappa V. "Preparation of Tirumala Srivari Laddu: A Critical Study". *Global Journal for Research Analysis* 4.4 (2015).
6. Intellectual Property of India. "Registration details of Geographical Indications. Patents/Designs/Trade Marks/Geographical Indications, Mumbai.
7. Smartt J and Nwokolo E. "Food and feed from legumes and oilseeds". Springer-Verlag, New York Inc. (1996): 419.
8. United States Department of Agriculture. USDA National Nutrient Database for Standard Reference, Release 22 (2009).
9. Tirupati Tirumala Devasthanam. "Application for registration of Tirupati laddu as Geographical Indication". TTD Administrative building, Tirupati, Andhra Pradesh, India (2008): 11.
10. Sahin S and Sumnu SG. "Physical Properties of Foods". Springer Science + Business Media (2006): 254.
11. Bhattacharya S., *et al*. "Rheology of Bengal gram (Cicerarietinum) flour suspensions". *International Journal of food Engineering* 17.2 (1992): 83-96.
12. Chhinnan MS., *et al*. "Rheological characterization of grain legume aastes and effect of hydration time and water level on apparent viscosity". *Journal of Food Science* 50.4 (1985): 167-1171.

13. Mukprasirt A., *et al*. "Rheological Characterization of Rice Flour-Based Batters". *Food Engineering and Physical Properties* 65.7 (2000): 1194-1199.

14. Wang HH., *et al*. "Flow behavior and rheological models of rice flour pastes". *Journal of Food Process Engineering* 22.3 (1999): 191-200.

15. Ravi R and Bhattacharya S. "Flow behavior of chickpea (Cicerarietinum L.) flour dispersions: Effect of additives". *Journal of Food Engineering* 65.4 (2004): 619-624.

16. Bhattacharya S and Bhattacharya S. "Flow behavior of cooked maize flour suspensions and applicability of mathematical models". *Journal of Food Process Engineering* 17.3 (1994): 263-278.

17. Ravi R and Susheelamma NS. "Simultaneous Optimization of a Multi-response System by Desirability Function Analysis of Boondi-making: A Case Study". *Journal of Food Science* 70.8 (2005): 539-547.

18. Chetana R. "Studies on the use of sucrose alternatives in traditional sweetmeats". Thesis submitted to the University of Mysore, India for Doctor of Philosophy in Food Science (2004): 210.

19. Murthy KV., *et al*. "Optimization of process parameters for boondi preparation". *Journal of Food Science and Technology-Mysore* 45.2 (2008): 123-126.

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