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Research Paper

Studies in Determination of Gelatinization Temperature of Wheat Batter Prepared from Wheat Grains Soaked at Varied Temperatures – A Rheological Perspective

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Abstract

Traditional Indian cereal based fermented food products like *Kurdi*(Maharashtra) and *Seera*(Himachal Pradesh) are prepared from batter of fermented wheat grains. These wheat batters were prepared by soaking wheat grains (*TriticumAstivum L*., variety: PBN51) in water at different temperatures (30, 37.5 and 45°C) for four days (natural fermentation), crushed, centrifuged and characterized for rheological properties.Prepared wheat batters were characterized for rheological properties like viscosity (Pa.s) vs shear rate (s^{-1}), viscosity (Pa.s) vs shear stress (Pa), loss modulus/ storage modulus/ Tan δ/ complex viscosity vs temperature. It was determined that the viscosity and gelatinization temperature of the wheat batters decreased with increase in the soaking temperature of the wheat grains.

Keywords: wheat grains, rheological properties, temperature, gelatinization, loss modulus, soaking

Fermentation is an age old method used for preserving foods. (Borgstorm, 1968) Various micro-organisms are utilized in the procedure for preparing consumable food products. (Wood, 1997) Fermented foods are one of the important items of the human diet. These traditional fermented food products are a household art prepared by using relatively simple procedures and equipments. (Battcock and Azam-ali, 1988; Sankaran, 1998; Aidoo *et al*., 2006) Fermented foods like *bhaatijaanr*,*idli*, *dosa*, *kurdi*, *seera*etc, are some of the items largely consumed in Indian Subcontinent. (Thakur *et al*., 2004; Beuchat, 1983; Soni *et al*., 1985; Batra, 1986; Tamang and Thapa, 2006; Thapa and Tamang, 2004)

Benefits of consumption of fermented food products are: (Tamang *et al.,* 1988)

- Health encouraging effects,
- Enhancement of flavor, manifestation, nutritional worth
- Improvement in storage stability
- Reduction in cooking time
- Variety in the diet.

Fermented food products like *idli*, *dosa*, *dhokla*, *khaman*, *wadi*, *papad* and *kinema* prepared in varied parts of India, have been well studied and recognized.However there is no detailed study reported for similar foods like *kurdi* an indigenous food item prepared largely in state of Maharashtra, India. (Nout and Sarkar, 1999; Nout *et al*., 2007) *Kurdi* is prepared by fermenting wheat grains by soaking in water and subsequent crushing (Thakur *et al*., 2004), which is then thermally gelatinized, hand extruded and dried. (Beuchat, 1983) Authors have not mentioned the fermentation temperature of *Kurdi*, as it varies from region to region in the state of Maharashtra in India. However, average temperature in Maharashtra varies from 25 to 45°C. (NCC, 2005) Thus, it can be prepared in any of these temperature ranges. Surve *et. al.,* (2014) modeled the flow behavior of this wheat batter, prepared by fermenting wheat grains at 30, 37.5 and 45°C – simulating the climatic conditions in Maharashtra, Indiausing the non-Newtonian fluid model, utilized for preparing *kurdi,*. The *Kurdi* preparation is ahouse-hold art passed from mother to daughter. Similar type of food named *Seera*, also called *Nishasta*, had been prepared in Himachal Pradesh, India. (Thakur *et al*., 2004) They reported the preparation of *Seera* at 30°C, using the similar procedure as mentioned above.

*Kurdi*is largely a traditional household product prepared by homemakers in the state of Maharashtra for their own consumption. This product has not been commercialized and thus there is no automated machines preparing it. However, like many other traditional Indian food stuffs *jaljeera*, *dahi*, various type of *pickles*etc which are commercialized undergo preparation in automated plants wherein, flow behavior and thus rheological aspects play an important role, *kurdi*can also becommercialized one day. Knowledge of the rheological properties of this fermented food dispersionsis required for quality control, product development; sensory evaluation, process design, consistency and for process scale up. (Hsia *et al*., 1992; Sanz *et al*., 2005) and dough (Uthayakumaran *et al*., 2002; Izydorczyk, 2001; Campos, 1997; Lazaridou *et al*., 2007). Rheological properties are amongst the most important physical properties defining the flow behavior of wheat batter used in the preparation of *kurdi*. However, there is no comprehensive information on the rheological behavior of this wheat batters prepared from fermented wheat grains. The main aim of this research is the determination of the gelatinization temperature of the wheat batter prepared from fermented wheat grains soaked in water at varied temperatures and understand its effect on the flow properties of the material.

Materials and Methods

Commercial wheat grains (*Triticum Astivum L*., variety: PBN51) was procured from Wheat Research Station, Vasantrao Naik MarathwadaKrishiVidyapeeth, Parbhani, Maharashtra, India. Proximate composition of wheat grains, determined as per AOAC (1990), is listed in Table 1.

Table 1. Proximate composition of wheat (PBN51)

Sr. No.	Constituent (%)	Mean ± S.D.
1.	Moisture	8.8 ± 0.3
2.	Fat	2.5 ± 0.2
3.	Protein*	3.9 ± 0.5
4.	Ash Content	1.5 ± 0.2
5.	Crude Fibre Content	1 ± 0.2
6.	Carbohydrate by difference	82.3 ± 1.2

* Calculated as N x 5.7.

Preparation of wheat batters

300 g wheat grains (variety: PBN51) were soaked in 900 ml water and incubated at different temperatures viz. 30, 37.5 and 45°C, for fermentation to take place. These temperatures were selected to observe the effect of temperature on the time required for the fermentation process. Water was replaced after every 8 h so as to get fresh growth of

natural flora of micro-organisms.This helps to have better natural fermentation of the soaked wheat grains. Water was disposed of on the fourth day and the fermented wheat grains were crushed with the help of a grinder (Anjalis grinder, Mumbai, India) at 3000 rpm for 40 s. Wheat branwas separated by filtration with a muslin cloth. Obtained filtrate was centrifuged (RemiCompufuge, Mumbai, India) at 4000 rpm for 7 min, sedimentingdown the carbohydrate (starch). Supernatant was discarded and the residue (i.e. wheat batter) was analyzed for rheological characteristics. (Thakur *et al.*, 2004). Prepared batter samples were equilibrate for at least 1 h before any rheological analysis.

Rheological analysis

A Rheometer (MCR 101, Anton Paar, Austria) equipped with a parallel plat assembly was used to obtain the rheological data of the wheat batters prepared from fermented wheat grains. Parallel plates having diameter of 25 mm (D-PP25-SN0) were utilized. Plates were a distancedby 0.5 mm during the analysis. Rheoplus/32V3.40 software, supplied by the manufacturer, was used for rheological data investigation. Temperature of rheological testing was maintained constant at 30°C. Batter samples were placed on the rheological peltier for 2 min of relaxation time before any measurement. Twenty five shear stress/shear rate data points were obtained, at 6 points/decade, during the shearing of the samples from 0.01 s^{-1} up to a shear rate of 100 s^{-1}. Test was performed in the experimental time of 200 s (Bhattacharya and Bhat, 1997). The whole process of sample preparation was repeated thrice, while all rheological investigations were performed on duplicate samples.

Frequency and strain sweeps were conducted to obtain the linear viscoelastic range. Frequency and strain were then fixed at 1Hz and 1%, respectively. Temperature sweeps involved heating at a rate of 2°C/min from 30 to 80°C. The frequency was fixed at 1 Hz. Duplicate scans were performed, with the complex viscosity (η*), storage modulus (G'), loss modulus (G") and Tan δ (ratio of loss modulus to storage modulus, G"/G').

Results and Discussion

Viscosity vs Shear rate

Figure 1 is a plot viscosity (Pa.s) vs shear rate (s^{-1}) data points obtained for the wheat batters prepared from wheat grains soaked at 30, 37.5 and 45°C. Whereas, the values of zero-shear viscosity (i.e. viscosity at very low shear rate, in our case the shear rate was 0.1 s^{-1})obtained for the batters are listed in Table 2.

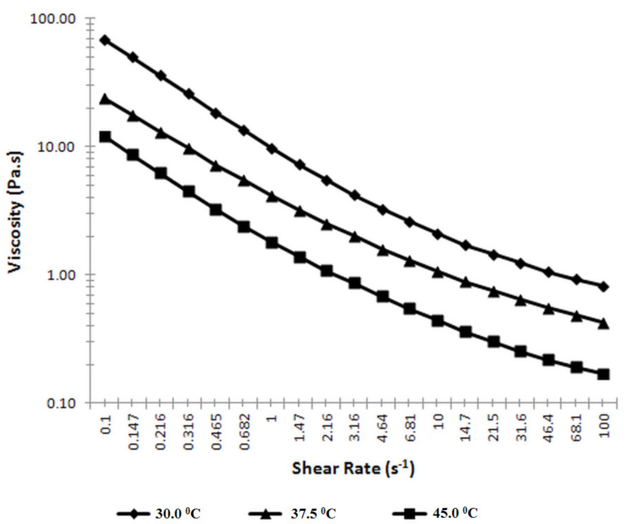

Fig. 1. Plot viscosity (Pa.s) vs shear rate (s^{-1}) data points obtained for the wheat batters prepared from wheat grains soaked at 30, 37.5 and 45°C

Table 2: Values of zero-shear viscosity obtained for the prepared wheat batters

Soaking Temperature (°C)	Zero-shear viscosity (Pa.s)
30.0	136.45 ± 10.36[a]
37.5	99.17 ± 4.67[b]
45.0	23.94 ± 1.19[c]

a-c Different subscripts for data in each colum represent significant differences (*P*<0.05)

Viscosity of the batter samples decreased with increase in shear rate. This behavior was consistent in all the analyzed batters. Thus, all the batter samples exhibited shear thinning behavior and are non-Newtonian in nature. It was determined that the viscosity of the batter samples decreased with increase in the soaking temperature of the wheat grains. Wheat grain consists of about 83% carbohydrate. Due to soaking of the wheat grains, the bran of the grain gets loosened up. This makes the carbohydrate of the grain easily available to the natural flora of micro-organisms present in water. These natural flora of micro-organisms are unknown for this type of fermentation process (Singhal, 2005). However, they could be any of these types: bacterias like *P. pentosaceus*, *P. acidilactici*, *Pediococcus sp.*, *Lactobacillus sp.*, or/and fungi like *R. oligosporus*, *A. oryzae*, *S. rouxii*, *S. cerevisiae*. (Singhal, 2005; Knorr, 1998; Hui and Khachatourians, 1995; Hoover and Steenson, 1993; Boskov-Hansen *et al.*, 2002) These micro-organisms brings about hydrolysis of the 1,4-α and/or 1,6-α linkages of the carbohydrate, degrading it to form fermentable sugars. (Goyal*et al.*,2005; Gupta *et al.*,2003) Thus, converting the high molecular weight carbohydrate into low molecular weight fermentable sugars. Also, the acids produced during fermentation process lowers the pH of the batter samples, increasing the activity of micro-organisms. This furtheraccelerates the fermentation process. (Fox and Mulvihill, 1982) Macromolecular structure of carbohydrate imparts higher amount of resistance on the rotating spindle of rheometer. This happens due to the entangled structural arrangement of carbohydrate, increasing the viscosity and zero-shear viscosity. However, the degradation of carbohydrate to fermentable sugars decreases the number of such structural entanglements of the carbohydrate in the wheat batter; reducing the intensity of resistance imparted by it on the rheometer spindle, thus, decreasing the viscosity and zero-shear viscosity. (Cooper-White and Mackay, 1999) Increase in the soaking temperature of wheat grains; increase the activity of the micro-organisms, leading to increased hydrolysis of carbohydrate producing more of fermentable sugars. (Mheen and Kwon, 1984) Thus, more of the polymeric structure of the carbohydrate will be broken down into the low molecular weight fermentable sugars, further reducing the intensity of resistance imparted by it to the rotating spindle of the rheometer, decreasing viscosity and yield stress. Zero-shear viscosity decreased by about 27.3 % for wheat batters prepared from wheat grains soaked at 37.5°C and 82.5 % for those prepared from wheat grains soaked at 45°C.

Viscosity vs Shear stress

Flow-curves are generally plotted as viscosity vs shear rate. However, such types of curves are not precise enough to express the quality of the data as that obtained from the plot of viscosity vs shear stress. Also, in terms of actual applications, the dependence of flow on shear stress is more suitable to be studied.

Plot of viscosity vs shear stress obtained for the prepared wheat batters is illustrated in Figure 2. It was determined that the viscosity of the batters decreased with increase in

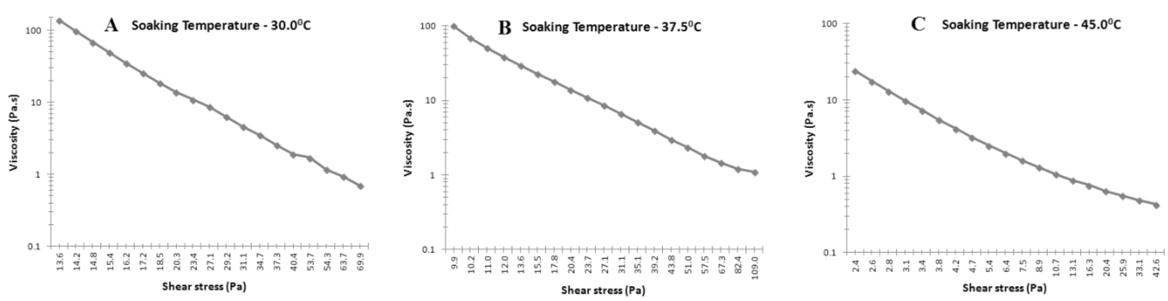

Fig. 2. Plot of viscosity vs shear stress obtained for the prepared wheat battersprepared from wheat grains soaked at 30, 37.5 and 45°C

shear stress. However, the decrease in viscosity with respect to shear stress is steeper as compared to that observed with shear rate. Thus, shear stress affects viscosity in higher proportion as compared to shear rate. Decrease in viscosity with increase in shear stress is attributed to the increased rupturing of the carbohydrate molecules (present in the batter) at higher shear stress than compared to lower shear stress.

Thus, the study of viscosity vs shear rate and viscosity vs shear stress, suggest that the high soaking temperature of wheat grains brings about higher conversion of carbohydrate structure into fermentable sugars. Thus, it will lead to its gelatinization at lower temperature. This can be suggested on the basis that, fermentable sugars being lower in molecular weight will get easily loosened up by the water molecules, decreasing the number and size of crystalline regions, as compared to the high molecular weight carbohydrate structure, making easy penetration of water molecules.

Analysis of Gelatinization temperature

Three separate phases of transformation were observed in G' (storage modulus) during the thermal scanning. These phases were observed in all the batter samples (Figure3). The G' originated at around 100, 10 and 4 Pa for the batter samples prepared from wheat grains soaked at 30, 37.5 and 45°C respectively; whereas, increased markedly when temperature rose above 50, 40 and 35°C respectively, before reaching a stable high value in the range of 60-80°C. In the first phase (<45°C), energized molecules softened the batter. Second phase characteristics are attributed to carbohydrate gelatinization. Third phase characteristics are believed due to mixture stability consisting of gelatinized carbohydrate molecules, representing a temporary steady state. (Chen *et al*., 2008) Batters prepared from the wheat grains soaked at higher temperatures shifted the second phase of the G' curve to lower temperature range. This was attributed to the increased hydrolysis of the carbohydrate brought about at higher soaking temperature, due to the increased activity of the natural flora of micro-organisms. Thus, increase in soaking temperature of the wheat grains to 37.5 and 45°C brings about 20 and 30%, respectively, decrease in the gelatinization temperature of the batter samples.

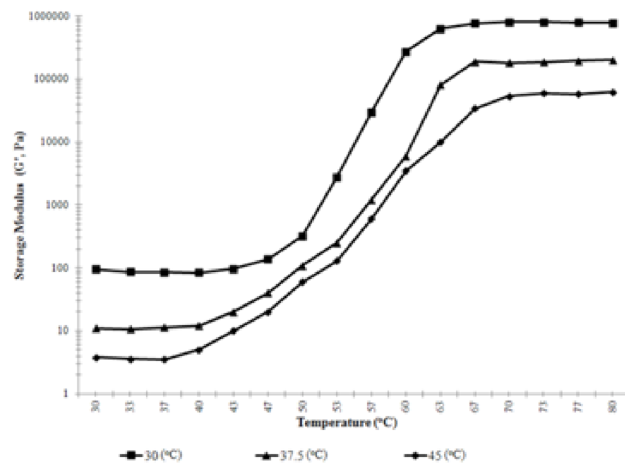

Fig. 3: Plot of storage modulus (G') vs temperature (^{0}C) obtained for the prepared wheat battersprepared from wheat grains soaked at 30, 37.5 and 45°C

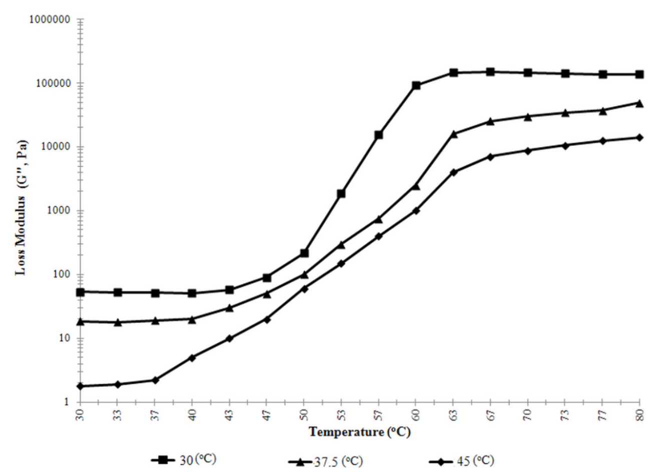

Fig. 4: Plot of loss modulus (G") vs temperature (^{0}C) obtained for the prepared wheat battersprepared from wheat grains soaked at 30, 37.5 and 45°C

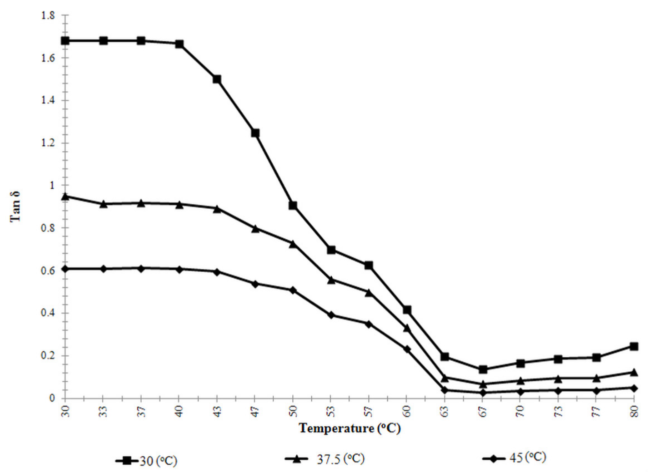

Fig. 5: Plot of Tan δ (G"/G') vs temperature (⁰C) obtained for the prepared wheat battersprepared from wheat grains soaked at 30, 37.5 and 45°C

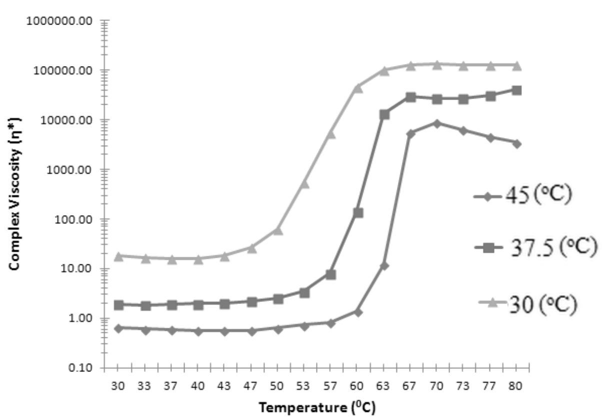

Fig. 6: Plot of Complex Viscosity vs temperature (⁰C) obtained for the prepared wheat battersprepared from wheat grains soaked at 30, 37.5 and 45°C

G" (Loss modulus) curves were similar to those of G' curves during thermal scanning (Figure4). Batters prepared from wheat grains soaked at higher temperatures exhibited lower G" values. Furthermore, the G" reached stable values above 60°C. Tan δ (Figure5) values of the batter samples decreased with increase in the soaking temperature of the wheat grains. Generally, point of intersection between G' and G" curves is considered to be the gelatinization temperature (Clark and Ross-Murphy, 1987). Nevertheless, prior to thermal gelatinization, G' is larger than G". However, G'>G" (i.e. Tan δ < 1) cannot be always considered to be the only precondition to determine thermal gelatinization temperature. (Lai *et al.*, 1997)

Thus, rheological analysis can be utilized to estimate and understand the gelatinization temperature of the wheat batters prepared from wheat grains soaked at varying temperatures.

Complex viscosity vs Temperature

The complex viscosity curves obtained for the batter samples on thermal scanning are demonstrated in Figure 6. Soaking temperature of the wheat grains definitely affected the flow properties of the batters prepared from it. The batter is a mixture in which the interactions between the ingredients influence its quality and functional properties especially the gelatinization temperature. Increase in soaking temperature of the wheat grains changed batter flow properties, reduced gelatinization temperature and enhanced viscosity. Increase in soaking temperature of the wheat grains used to prepare batterdisplayed low complex viscosity in the study.

Conclusion

Wheat batters prepared from wheat grains soaked at varied temperatures were successfully characterized for rheological properties. Wheat batter samples demonstrated non-Newtonian shear-thinning behavior. Viscosity of the wheat batter decreased with increase in the soaking temperature attributed to the hydrolysis of the macromolecular structure of carbohydrate, present in the wheat grains, converting it to low molecular weight fermentable sugars. This also resulted in the decrease in the gelatinization temperature of the wheat batter as determined from loss modulus, storage modulus and complex viscosity. Thus, it can be said that rheological analysis can be utilized to estimate and understand the rheological properties of the wheat batters prepared from wheat grains soaked at varied temperatures.

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