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Studies in rheological properties of wheat batter prepared from wheat grains fermented at different temperatures used to prepare *Kurdi* - a traditional Indian food

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Abstract

Wheat batter prepared from fermented wheat grains is used to prepare traditional Indian food products like *Kurdi* in Maharashtra and *Seera* in Himachal Pradesh. These batters were prepared by soaking wheat grains (*Triticum astivum* L., PBN51) in water at different temperatures – 30, 37.5 and 45°C, crushed, filtered and analyzed. Reducing sugars, Total Plate Count and titrable acidity increased, whereas, pH, peak temperature, endothermic peak area decreased after fermentation (soaking) and also with increase in fermentation (soaking) temperature. Yield stress decreased by 65% and 82% for wheat grains soaked at 37.5° and 45°C, respectively. Of the various rheological flow models tried for model fitting, Cross model well-fitted the observed flow trend in the wheat batter with a root-mean-square error of less than 1%. Viscosity and yield stress of the wheat batter decreased with increase in soaking temperature, which was confirmed by the analysis of flow behavior index and consistency index.

Introduction

Fermentation is one of the oldest method of preserving foods and beverages, which had been practiced for thousands of years by the primitive people (Borgstorm, 1968). Fermentation is a process by which consumable food products are prepared by use of various micro-organisms (Wood, 1997). Fermented food products prepared from cereals are an integral part of the diet of the people in many parts of the world. The preparation of cereal based traditional fermented food products and other indigenous beverages remains today as a household art; prepared using relatively simple procedures and equipments (Sankaran, 1998; Aidoo *et al*., 2006; Aloys and Angeline, 2009). Cereal based fermented foods and alcoholic beverages like *idli*, *dosa*, *jalebies*, *kurdi*, *seera*, *bhaati jaanr*, *kodo ko jaanr* etc. have been a part of Indian traditional fermented foods of varied localities, a practice protected by tradition. (Mukherjee *et al*., 1965; Beuchat, 1983; Soni *et al*., 1985; Batra, 1986; Thakur *et al*., 2004; Thapa and Tamang, 2004; Tamang and Thapa, 2006). Now-a-days fermented foods are receiving world attention due to their disease-preventing and health promoting effects. Improvement of flavor, appearance, nutritional value and storage stability with reduction in cooking time are the additional benefits of fermented foods. Fermented foods also provide variety in the diet. (Tamang *et al*., 1988). Cereal legume based fermented foods like *idli*, *dosa*, *dhokla*, *khaman*, *wadi*, *papad* and *kinema* from various parts of India have been well studied and documented; however, there is no proper documentation of similar foods, indigenous to the state of Maharashtra (*kurdi*) in India (Nout and Sarkar, 1999; Nout *et al*., 2007).

Kurdi is a traditional Indian cereal based fermented food prepared by soaking, fermenting and crushing wheat grains (Thakur *et al*., 2004), which is subsequently thermally gelatinized, hand extruded and dried (Beuchat, 1983). The preparation of *kurdi* is an art of technology and is a family secret passed from mother to daughter. Since, time immemorial kurdi is known as a ceremonial fried food of special significance to the village people of Maharashtra. It marks a special occasion of the Maharashtrians such as marriage, religious and cultural festivals. Similar type of food product named *Seera*, also called *Nishasta*, is prepared in the state of Himachal Pradesh of India (Thakur *et al*., 2004).

Knowledge of the rheological behavior of fermented food dispersion is essential for quality control, product development, sensory assessment, process design, standardization and for process scale up. Several studies have reported the viscoelastic properties of flour batter (Hsia *et al*., 1992; Naruenartwongsakul *et al*., 2004; Sanz *et al*., 2005) and dough (Campos *et al*., 1997; Izydorczyk, 2001;

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Uthayakumaran *et al*., 2002; Lazaridou *et al*., 2007). Similarly, rheological properties are amongst the most important physical properties defining the flow behavior of wheat batter, prepared from fermented wheat grains, used for preparing *kurdi*. Nevertheless, there is currently no comprehensive rheological properties information available on the flow behavior of wheat batter prepared from fermented wheat grains. The main aim of this research includes (a) determination of the rheological behavior of wheat batter prepared from fermented wheat grains and (b) assessment of the suitability of the rheological model(s) to describe such batter. Also, reducing sugars, Total Plate Count (TPC), titrable acidity, pH and thermal properties (differential scanning calorimetry) of the wheat grains were determined both before and after the fermentation (soaking) process.

Materials and Methods

Materials

Commercial wheat grains (*Triticum Astivum* L., variety: Pbn - 51) was procured from Wheat Research Station, Vasantrao Naik Marathwada Agricultural University, Parbhani, Maharashtra, India. Proximate composition of wheat grain, determined as per AOAC (1990), is listed in Table 1. Ethanol, Dinitrosalicylic acid reagent and potassium sodium tartarate (Rochelle salt) were procured from S.D.Fine Chem. Pvt. Ltd., Mumbai, India. Saline solution and nutrient agar were obtained from HiMedia Pvt. Ltd., Mumbai, India.

Procedure to prepare wheat batter from fermented (soaked) wheat grains

100 g wheat grains were soaked in 300 ml water and were incubated at varied temperatures - 30, 37.5 and 45°C, for fermentation to take place. Water was replaced after every 6 h so as to get fresh microbial growth and thus to have better fermentation of the wheat grains. Water was discarded on fourth day and the softened wheat grains were crushed (Anjalis grinder, Mumbai, India) at 2500 rpm for 30 s; and separated of whole wheat bran (i.e. bran and germ portion) by filtering through the muslin cloth. Filtrate was centrifuged (Remi Compufuge, Mumbai, India) at 3000 rpm for 10 min to settle down the batter. Supernatant was discarded and the residual wheat batter was taken for rheological analysis. This methodology is largely used to prepare traditional Indian fermented food products such as *Seera* (*Nishasta*) (Thakur *et al*., 2004) in Himachal Pradesh and Kurdi (Beuchat, 1983) in Maharashtra. The prepared wheat batter had water content of about

Table 1. Proximate composition of wheat grain (variety: Pbn - 51)

Sr. No.	Constituent	Composition (%)*
1.	Moisture	8.8 ± 0.3
2.	Fat	1.5 ± 0.2
3.	Protein	5.4 ± 0.5
4.	Ash Content	1.0 ± 0.2
5.	Crude Fibre Content	1 ± 0.2
6.	Carbohydrate by difference	82.3 ± 1.2

* Values are mean ± SE of three independent determinations.

35%. Batters were allowed to equilibrate for 1 h before rheological analysis. Reducing sugars, TPC, titrable acidity, pH and thermal properties (differential scanning calorimetry) of the wheat grains were determined both before and after the fermentation (soaking) process at varied temperature.

Estimation of reducing sugar by dinitrosalicylic acid (DNS) method

100 mg sample was twice extracted for reducing sugars in hot 80% ethanol (5 ml each time). Supernatant was collected and evaporated by keeping it on a water bath at 80°C; which was then added with 10 ml distilled water. 1 ml of the extract was pipetted in a test tube and added with 3 ml of distilled water and 3 ml of DNS reagent. Prepared contents were boiled on a water bath for 5 min. When the contents of the tube were still warm, it was added with 1 ml of 40% Rochelle salt solution. Content of the test tubes were cooled to room temperature (approximately 30°C) and read for intensity of dark at 510 nm. Standard was run with 100 µg glucose. (Sadasivam and Manickam, 2008; Arora *et al.*, 2010).

Enumeration of total plate count (TPC)

TPC of the sample was enumerated using nutrient agar medium. 1 g of sample was added with 9 ml of sterile normal saline solution. Further, serial dilutions up to 10^{-7} were made. Each dilution (1 ml) was pour plated in sterilized petriplates, incubated at 37°C for 48 h. Colonies were counted only after getting a final count between 30-300 in a plate by pour plating method using a colony counter. (Nisha *et al*., 2005).

Titrable acidity and pH

Titrable acidity was reported in terms of g lactic acid/100 ml using the standard method (Amerine *et al*., 1967). The pH was measured by digital pH meter.

Differential scanning calorimetry (DSC)

A TA-60WS DSC (Shimadzu Analytical Pvt. Ltd., Singapore) was utilized to measure the degree of gelanization properties for the sample. 20 mg wheat batter sample was transferred in to a DSC pan. The pan was hermetically sealed and inserted in the calorimeter. Thermal curves included onset temperature (T_o), peak temperature (T_p), endothermic peak area (H_e) and endset temperature (T_e). Heating rate was maintained at 10°C/min from 30 to 250°C. DSC-60 software, supplied by the instrument manufacturer, was used to determine the mentioned temperatures and peak area. The software drew a tangent line at the steepest point of the DSC curve and a baseline connecting the starting and the ending points of the peak. The intersections of the baseline with the DSC curve determined the onset and ending temperatures. Gelatinization energy (endothermic peak area, H_e) was calculated by drawing a straight line between onset temperature and ending temperature and was recorded as J/g.

Rheological analysis

A rheometer (MCR 101, Anton Paar, Austria) with a parallel plat assembly was used to investigate the rheological behavior of the wheat batters prepared from fermented wheat grains. Parallel plates (diameter: 25 mm, D-PP25-SN0) were separated by a distance of 0.5 mm during the rheological analysis. The rheological data analysis was performed using Rheoplus/32V3.40 software supplied by the manufacturer. A temperature of 30 ± 0.5°C was maintained constant during the rheological measurement. Batter samples were set on the rheological peltier for 3 min of relaxation before each measurement. Grease was applied on the exposed surface of samples to prevent sample dehydration. Twenty five shear-stress/shear-rate data points were obtained, at 6 points/decade, during the shearing of the samples from 0.1 s^{-1} up to 100 s^{-1} shear rate within the experimental time of 200 s (Bhattacharya & Bhat, 1997). The whole process of sample preparation was repeated twice, while all rheological investigations were performed on triplicate samples.

Shear-stress and shear-rate data were fitted to the rheological models like Power law (equation 1), Herschel-Bulkley (equation 2), Bingham plastic (equation 3), Casson (equation 4) and Cross (equation 5). The flow behavior index and fluid consistency index for the best-fitted equation was estimated by employing a non-linear regression analysis of viscosity/shear-rate data using the software (Rheoplus/32V3.40) supplied by the equipment manufacturer.

$$\sigma = k_p(\gamma'^{np}) \quad \text{equation 1}$$

$$\sigma = \sigma_{0HB} + k_{HB}(\gamma'^{nHB}) \quad \text{equation 2}$$

$$\sigma = \sigma_B + n_B(\gamma') \quad \text{equation 3}$$

$$\sigma^{0.5} = \sigma_c^{0.5} + n_c(\gamma'^{0.5}) \quad \text{equation 4}$$

$$\sigma = \sigma_\infty + [(\sigma_0 - \sigma_\infty)]/[1 + k_{CR}(\gamma')]\, n_{CR} \quad \text{equation 5}$$

Where, σ is shear-stress (Pa), γ' is shear-rate (s^{-1}), k is fluid consistency index ($Pa.s^n$), n is flow behavior index (dimensionless), and σ_0 is the yield stress (Pa); the subscripts P, HB, C, B and CR indicate for Power Law, Herschel-Bulkley, Casson, Bingham Plastic and Cross models respectively. Suitability of the rheological models was judged by determining the root-mean-square (rms) error (equation 6):

$$\text{rms error} = \sqrt{\frac{\sum_{n=1}^{N}(W_{experimental} - W_{calculated})^2}{N}} \times 100$$

equation 6

where, N is the number of data points and W indicates shear-stress.

Yield stress of the samples was determined experimentally using the stress relaxation technique at a shear-rate of 3 s^{-1} (Bhattacharya & Bhattacharya, 1994a, 1996b; Latha *et al.*, 2002). Yield stresses were also calculated utilizing Herschel-Bulkley, Casson, Bingham Plastic and Cross models and compared with experimental data.

Statistical analysis

Statistical analysis was performed using the one-way analysis of variance and mean comparisons with Bonferroni correction ($P < 0.05$), with Microsoft Excel and the Stat Plus Add-In. (Berk and Carey, 1998).

Results and Discussion

Estimation of reducing sugar by dinitrosalicylic acid (DNS) method

Table 2 lists the reducing sugars obtained for the wheat grains, before and after soaking (fermentation) at varied temperatures. Reducing sugar content of the wheat grains after soaking increased significantly (4 fold) as compared to that before soaking. This might be due to the enzymatic hydrolysis of the carbohydrate to simpler sugars during soaking. When the wheat grains were soaked at higher temperatures (37.5 and 45°C), further significant increase in reducing sugars was observed. This increase could result from increased enzymatic hydrolysis of the carbohydrate during soaking. Reducing sugars in the soaked wheat grains may be utilized by the natural flora of micro-organisms as a carbon source. Thus, the final fermented wheat grains may ultimately contain a lower level of sugars than expected. It was reported that in the initial stages of fermentation, lower level of reducing sugars may be observed but

Table 2. Estimation of reducing sugars in the wheat grains before and after soaking (fermentation)

Soaking Temperature (°C)	Reducing Sugar Content (g/100 g)*	
	Before Soaking	After Soaking
30.0	0.54 ± 0.24	2.13 ± 0.16
37.5	0.56 ± 0.27	2.35 ± 0.19
45.0	0.55 ± 0.21	2.67 ± 0.21

*Values are mean ± SE of three independent determinations.

Table 3. Estimation of Total Plate Count in the wheat grains before and after soaking (fermentation)

Soaking Temperature (°C)	Total Plate Count (cfu/ml)*	
	Before Soaking ($x 10^4$)	After Soaking ($x 10^6$)
30.0	2.8 ± 0.2	5.2 ± 0.4
37.5	3.2 ± 0.4	7.2 ± 0.5
45.0	2.9 ± 0.2	7.5 ± 0.4

*Values are mean ± SE of three independent determinations.

with increased temperature, the reducing sugars may be utilized by the natural flora of micro-organisms and the fermented wheat grains may contain lower level of reducing sugars than expected (Sripriya *et al*., 1997; Sindhu and Khetarpaul, 2005).

Enumeration of total plate count (TPC)

Table 3 lists the TPC values obtained for the wheat grains, before and after soaking (fermentation) at varied temperatures. TPC of the wheat grains increased appreciably after the fermentation (soaking) process. TPC of wheat grains increased from 2.8 x 10^4 cfu/ml, before soaking, to 5.2 x 10^6 cfu/ml for those soaked at 30°C. This might be due to the fermentation of wheat batter, which favored for better growth of micro-organisms (Sripriya *et al*., 1997). TPC of the wheat grains increased with increase in soaking temperature; due to enhancement in the fermentation process (Sindhu and Khetarpaul, 2005). However, increase in TPC for wheat grains soaked at temperature above 37.5°C (i.e. 45°C) was not appreciable. Thus, it appears that the growth of natural flora of micro-organisms was well supported when wheat grains were soaked at 37.5°C (Arora *et al*., 2010).

Estimation of titrable acidity and pH

Values of titrable acidity and pH obtained for the wheat grains, before and after soaking (fermentation) in water at varied temperatures, are reported in Table 4. Non-fermented wheat grains (before soaking at any temperature) had titrable acidity of about 0.36 g lactic acid/100 ml and pH of about 6. A significant increase in titrable acidity and corresponding decrease in pH was observed after the fermentation of the wheat grains. Similar trend was observed with increase in soaking (fermentation) temperature. Reduction in pH and corresponding increase in titrable acidity may be due to the hydrolysis of carbohydrate into reducing sugars during fermentation, which was utilized by the natural flora of micro-organisms and converted to lactic acid (Sripriya *et al*., 1997). Similar trend had

Table 4. Estimation of titrable acidity and pH of the wheat grains before and after soaking (fermentation)

Soaking Temperature (°C)	Titrable acidity (g lactic acid/100 ml)*		pH*	
	Before Soaking	After Soaking	Before Soaking	After Soaking
30.0	0.36±0.02	1.81±0.05	6.02±0.01	5.4±0.06
37.5	0.37±0.04	1.97±0.07	6.03±0.02	5.1±0.04
45.0	0.36±0.02	2.23±0.08	6.02±0.02	4.7±0.04

*Values are mean ± SE of three independent determinations.

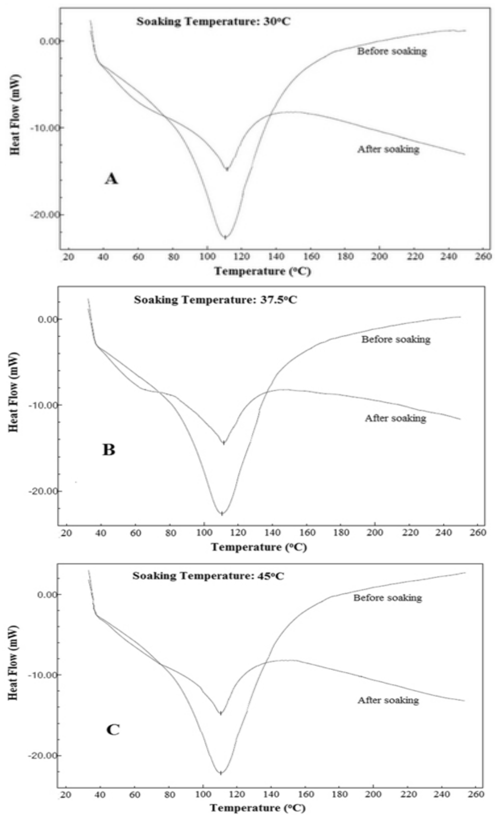

Figure 1. DSC thermograms obtained for the prepared wheat batters

been reported by Sindhu and Khetarpaul (2005), and Sripriya *et al*. (1997) in their studies of fermentation of cereal-legume blend and finger millet, respectively.

Differential scanning calorimetry (DSC)

Figure 1 shows the DSC thermograms obtained for the wheat grains, both before and after soaking (fermentation), at different temperatures (A-30°C, B-37.5°C, C-45°C), while the values of onset temperature (T_o), peak temperature (T_p), endothermic peak area (H_e) and endset temperature (T_e) are listed in Table 6. It was determined that there was no significant difference in the values of T_o, T_p, H_e and T_e for the wheat grain samples analyzed before soaking. However, T_p, H_e and T_e decreased, whereas, To increased significantly after soaking the wheat grains at varied temperature. Also the values of T_p, H_e and T_e decreased, while, that of T_o increased with increase in soaking temperature.

Non-fermented wheat grains contained large amount of high molecular weight carbohydrate structure, which required higher amount of heat (H_e)

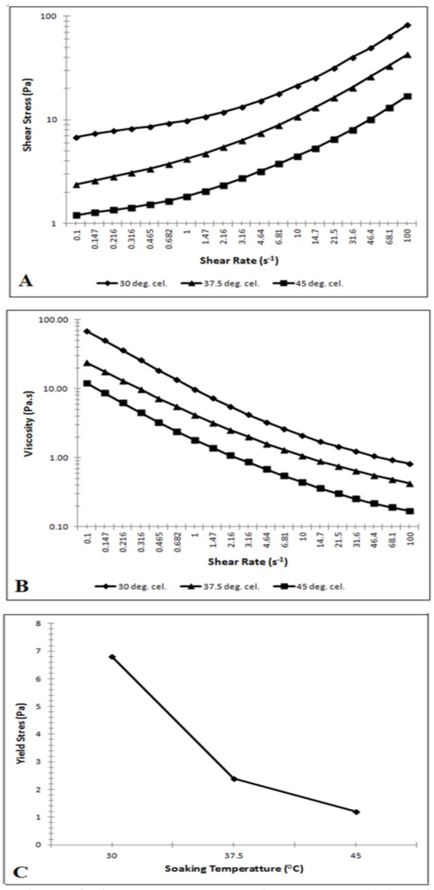

Figure 2. Plot of shear-stress vs shear-rate (A), viscosity vs shear-rate (B) and yield stress vs soaking temperature (C) obtained for the prepared wheat batters

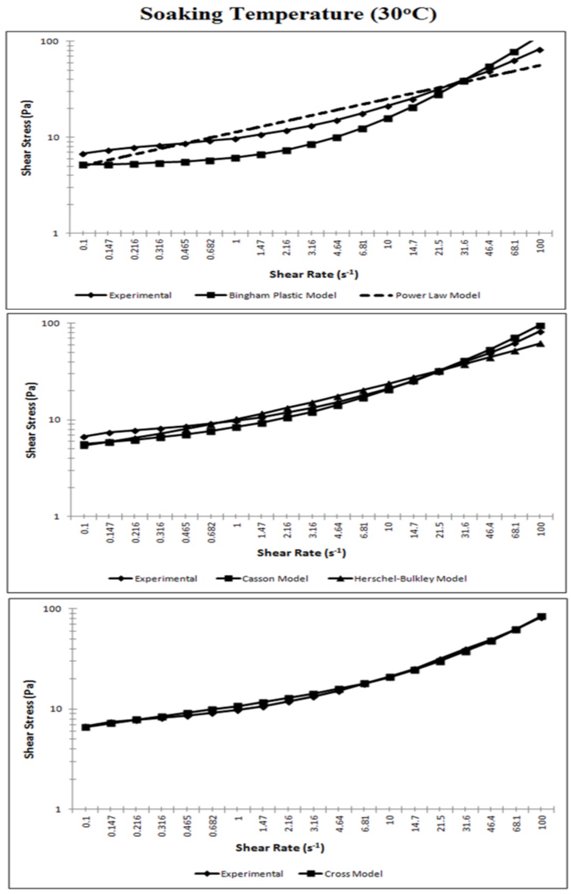

Figure 3. Model-fitted curves to the experimental data of the batters prepared from wheat grains soaked at 30°C

and temperature (T_p). However, the hydrolysis of the carbohydrate by the natural flora of micro-organisms during the fermentation stage (soaking) converted high molecular weight carbohydrate structure into low molecular weight reducing sugars. This reducing sugars acted as a plasticizer, lowering the T_p, H_e and T_e, with increase in T_o, of the wheat grains (Biliaderis *et al*., 1986). Increase in the soaking temperature of wheat grains, brings about increase in the activity of the natural flora of micro-organisms, leading to increased hydrolysis of carbohydrate, producing more of reducing sugars (Mheen and Kwon, 1984). Thus, more of the polymeric structure of the carbohydrate will be broken down into the low molecular weight reducing sugars; increasing the level of plasticization, further reducing T_p, H_e and T_e, with increase in T_o.

Determination of the rheological behavior of wheat batter prepared from fermented wheat grains

Figure 2 illustrates the plot of shear-stress vs shear-rate (A), viscosity vs shear-rate (B) and yield stress vs soaking temperature (C) obtained for the wheat batter prepared from fermented (soaked) wheat grains, prepared at varied soaking temperature. It was determined that yield stress, shear-stress and viscosity decreased, with increase in soaking temperature during fermentation. Also, it was determined that viscosity decreased with increase in shear rate. This behavior was consistent in all the wheat batter samples prepared from fermented wheat grains at various soaking temperature. Thus, all the batter samples demonstrated shear-thinning behavior (Yu, 2013). The error in repeatability of results was between 5 and 10% for all the batter samples.

Wheat grain used in our study consisted of about 83% carbohydrate, thus, forming its major component. Due to soaking of wheat grains, the bran of the wheat grain gets loosened up, making the carbohydrate of the wheat easily available to the natural flora of micro-organisms. These natural flora of micro-organisms are unknown for this type of fermentation process (Singhal, 2005), used for preparation of Indian traditional fermented food products like *kurdi* and *Seera.* However, they may 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* (Hoover and Steepson, 1993; Hui and Khachatourians, 1995; Knorr, 1998; Hansen *et al*., 2002; Singhal, 2005). These natural flora of micro-organisms hydrolyzes the 1,4-α and/or 1,6-α linkages

Table 5. Thermal characteristics of the wheat grains before and after soaking (fermentation)*

Soaking Temperature (°C)	Before Soaking				After Soaking			
	T_o (°C)	T_p (°C)	H_e (J/g)	T_e (°C)	T_o (°C)	T_p (°C)	H_e (J/g)	T_e (°C)
30.0	37.7a	111.5a	6.23a	140.5a	42.6a	110.1a	2.41a	126.8a
37.5	38.2b	111.0a	6.27a	141.2a	43.8a	108.9b	2.34b	124.8b
45.0	37.2a	110.8a	6.25a	139.9a	45.7b	107.4c	2.28c	124.0b

*Means within a column followed by the same letter are not significantly different ($P \leq 0.05$)

Table 6. rms error values obtained for the models fitted to the fermented wheat batter prepared viscosity curves prepared from wheat grains soaked at different temperatures

Soaking Temperature (°C)	Model Fitted	rms error (%)
30	Bingham plastic model	8.75
	Casson model	3.78
	Cross model	1.00
	Herschel-Bulkley model	5.56
	Power Law model	4.27
37.5	Bingham Plastic model	5.52
	Casson model	3.41
	Cross model	0.48
	Herschel-Bulkley model	2.59
	Power Law model	2.78
45	Bingham Plastic model	2.15
	Casson model	1.30
	Cross model	0.18
	Herschel-Bulkley model	1.27
	Power Law model	1.35

of the carbohydrate, degrading it to form reducing sugars; converting high molecular weight polymer structure of carbohydrate into low molecular weight reducing sugars. Also, the acids produced during fermentation, lowers the pH of the batter, thereby increasing the activity of micro-organisms, thus conversion accelerates (Fox and Mulvihill, 1982). High molecular weight carbohydrate imparts more resistance on the rotating spindle of the rheometer, due to the entangled structural arrangement of carbohydrate, increasing the viscosity and yield stress. However, the hydrolysis of carbohydrate to reducing sugars reduces the number of structural entanglement of the carbohydrate in the wheat batter. Thus, reducing the intensity of resistance imparted by it on the rheometer spindle, decreasing the viscosity and yield stress (Cooper-White and Mackay, 1999). Increase in the soaking temperature of wheat grains, brings about increased conversion of carbohydrate into the low molecular weight reducing sugars, further reducing the intensity of resistance imparted by the batter to the rotating spindle of the rheometer, decreasing viscosity and yield stress. Yield stress decreased markedly by about 65% for wheat grains soaked at 37.5°C and 82% for those soaked at 45°C.

Suitability of the rheological models

Certain common rheological models employed for model fitting in our data were Bingham plastic, Power Law, Casson, Herschel-Bulkley and Cross. Model-fitted curves to the experimental data of the batter prepared from wheat grains soaked at various soaking temperature like 30, 37.5 and 45°C are illustrated in Figures 3, 4 and 5, respectively.

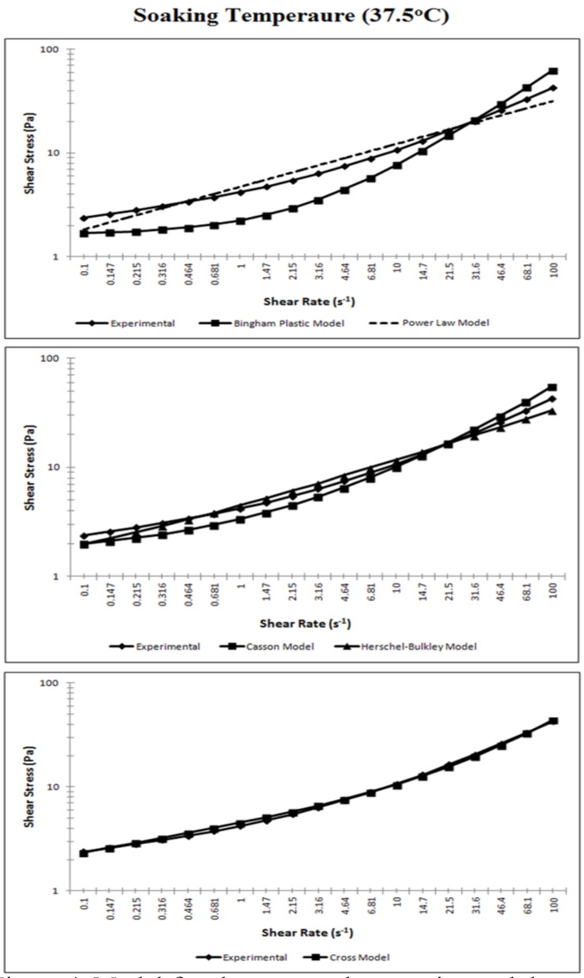

Figure 4. Model-fitted curves to the experimental data of the batters prepared from wheat grains soaked at 37.5°C

Whereas, the rms error values obtained for the fitted models are listed in Table 6.

Among the common rheological models attempted, the suitability of the Cross model (with experimental stress values) was superior to Power Law, Bingham plastic, Casson and Herschel-Bulkley models. Least rms error of below 1% was noted for the Cross model, while the second lowest was noted for Herschel-Bulkley model. However, highest rms error was obtained for Bingham plastic model.

Experimental and model-fitted yield stress values obtained for the wheat batter prepared using wheat grains soaked (fermented) at varied soaking temperature are illustrated in Fig. 6. Again, it was determined that yield stress values determined using Cross model were correlative with that obtained experimentally. Yield stresses determined by other models (Power Law, Bingham Plastic, Casson, Herschel-Bulkley) were lower than those obtained experimentally. Thus, it is appropriate to determine yield stress values using Cross model instead of using other rheological models.

Flow parameters (Figure 7) such as flow behavior index (n) increased from 0.75 to 0.84 (unit less)

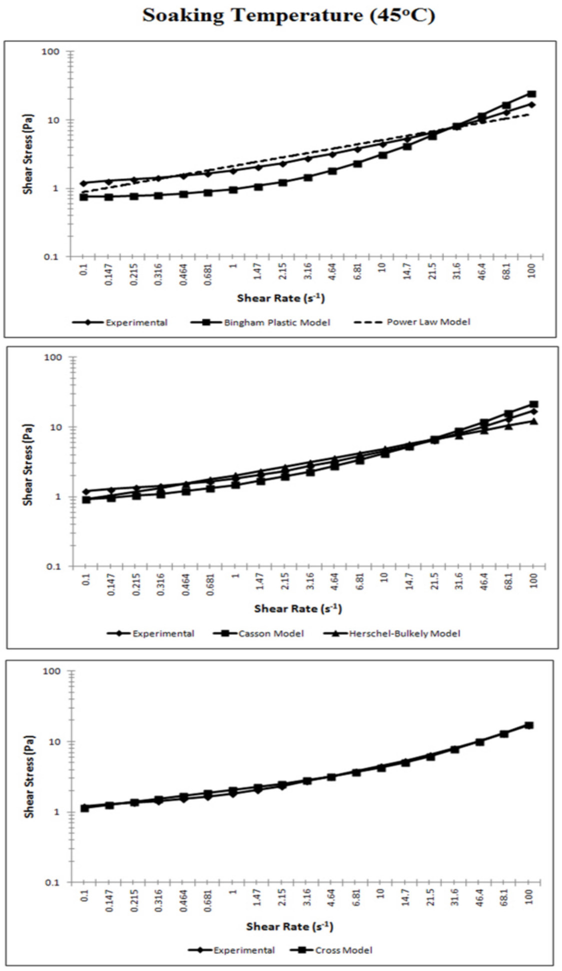

Figure 5. Model-fitted curves to the experimental data of the batters prepared from wheat grains soaked at 45°C

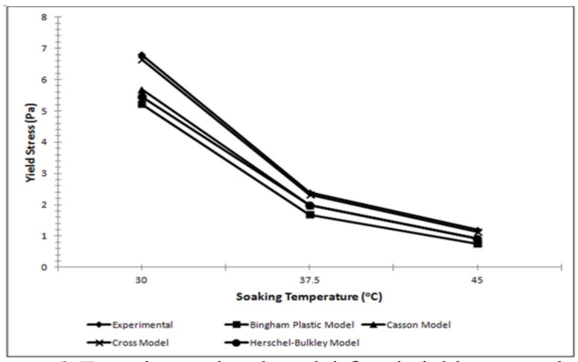

Figure 6. Experimental and model-fitted yield stress values obtained for the fermented wheat batter prepared using wheat grains soaked at varied soaking temperatures

with increase in soaking temperature of the wheat grains used for the preparation of batter. On the other hand, consistency index (k) of batter decreased from 109.81 to 60.39 Pa.s^n with the increase in wheat grain soaking temperature. This reflects lower batter viscosity and yield stress; which corroborates with the rheological characteristics observed during the shear stress study. Increased soaking temperature caused higher hydrolysis of the carbohydrate polymer chains breaking it down to reducing sugars. As the content of this low molecular weight reducing sugars increased,

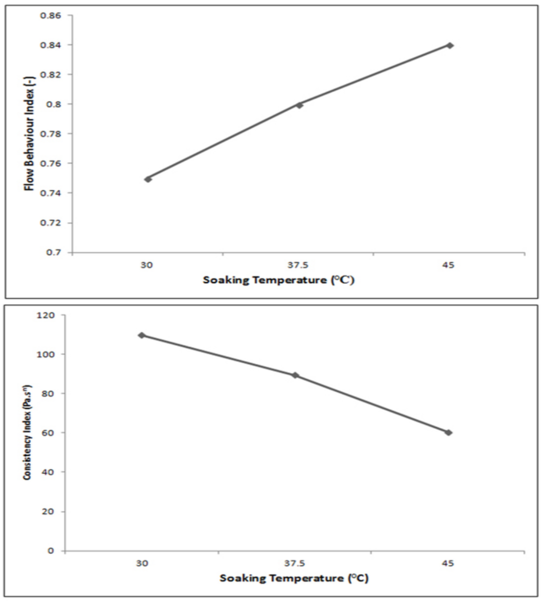

Figure 7. Flow parameters: flow behavior index and fluid consistency index, obtained for the prepared fermented wheat batters

it enhanced the flow behavior of the batter.

Conclusion

Wheat batter was successfully prepared from wheat grains soaked at varied temperatures – 30, 37.5 and 45°C. Appreciable increase in reducing sugars, TPC and titrable acidity, whereas, corresponding decrease in pH, T_p and H_e, were observed after fermentation, and also with increase in fermentation (soaking) temperature; which was attributed to the conversion of carbohydrate into the low molecular weight reducing sugars by the natural flora of micro-organisms. By measuring the rheological properties, it was determined that viscosity and yield stress of the batter decreased noticeably with increase in soaking temperature. Prepared wheat batter showed shear thinning behavior. Whereas, Cross model very well fitted the shear-stress and shear-rate data, with an rms error of below 1%, out of the different models tried like Bingham plastic, Casson, Herschel-Bulkley and Power law.

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