International Food Research Journal 20(4): 2005-2008 (2013)
Journal homepage: http://www.ifrj.upm.edu.my

Concentration dependent rheological behaviour of promising basmati and non basmati rice flour

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Article history

Received: 9 April 2012
Received in revised form: 17 February 2013
Accepted: 23 February 2013

Keywords

Rheology
Viscosity
Rice flour
Consistency
Flow behavior

Abstract

Rice is predominantly a starch richendosperm portionof paddy (*Oryza sativa*). It is an important cereal used as staple food by over half of the world population. About 90% of dry matter of milled rice is starch and the rest are non-starch components like protein, lipids and ash. Most of the rice based products in Indian sub continent especially in southern part of India are made from rice flour dispersion, slurry, paste or dough. Thus, dry grinded flour aqueous dispersions of white broken rice of genotype PUSA 1121 and PR 118 at different concentration levels (0.5 to 10% w/w) have been evaluated for rheological behavior. The rheological measurement of rice flour dispersion indicated concentration dependent shear thinning fluid at lower concentration and pseudo-plastic fluid behavior at higher flour concentration. Increase in solid concentration increased the consistency coefficient and apparent viscosity but decreased flow behavior index.

Introduction

Rheology is the science of deformation of matter includes the studies of deformation in relation to force and time. Rheological studies concentrate on three important parameters such as force, deformation and time for expressing the mechanical behavior. Thus, the studies on rheology perhaps help to understand how food constituent and structure responds to applied force and deformation (Yang *et al.*, 2004). The viscosity of the products are needed to determine the heat transfer rates, energy consumption with increase in concentration, and for controlling the temperature and flow rates of heating media to ensure continuous flow and gelling of food products. The flow behavior also influences the pump performance (Steffe, 1996).

About 90% of dry weight of milled rice is starch and the rest are non-starch components like protein, lipids and ash (Juliano, 1992). Rice starch is a glucose polymer composed of amylose and amylopectin. Amylose is primarily a linear chain of D-glucose united by α-1 → 4 linkages. Some amylose molecules have about 0.3-0.5% of α-1 → 6 branch linkage (Takeda *et al.*, 1990). Amylopectin is a branched polymer made up of α-1 → 4 and α-1 → 6 glycosidic linkages. The amylose content of non-waxy rice varies from 8 - 37% and waxy (glutinous) rice from 0.8 - 1.3% (Juliano and Perdon, 1975). The waxy rice flour is frequently used as a thickening agent for white sauces, gravies and puddings. Low amylose (9-20%) rice are preferred for processing crackers and biscuits, intermediate amylose (20-25%) rice is used for making extruded (dried) pasta and high amylose (> 25%) rice varieties are favored for parboiled rice, rice bread and noodles (Prasad *et al.*, 2012a). Rice being invaluable alternative source of carbohydrate is easily digestible and has rare allergic reactions. The absence of gluten provides an additional advantage makes rice particularly suitable as an alternative to wheat in bakery products especially suitable for the persons suffering from the physiological disorder of gluten sensitive enteropathy commonly termed as celiac disease (Prasad *et al.*, 2010).

Rice is the main base for the preparation of many indigenous fermented food products (like *idli*, *dosa*, *uttapam*, sake-an alcoholic beverage), sweets (*anarasa*, *khir*), *khichadi*, *pulav*, puffed and extruded products (Ghadge and Prasad, 2012). Most of the rice based products are made from rice flour obtained by different grinding methods (Prasad *et al.*, 2012a; Prasad *et al.*, 2012b) and its dispersion, slurry, paste or in the form of dough are required before final steaming, heating or frying carried out depending on the product requirement (Bhatia *et al.*, 2009). The rheological studies for different cereals under low moisture conditions have been examined (Remsen and Clark, 1978; Mackey and Ofoli,

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1990; Madeka and Kokini, 1992) and rheological parameters have been considered as an analytical tool to provide fundamental insights on the structural organization of food and play an important role in fluid heat transfer (Ahmed *et al*., 2009). Therefore, the objective of the present investigation was to examine the effect of concentration and varietal differences on the rheological properties foraqueous rice flour dispersions.

Materials and Methods

Paddy (*Oryza sativa*) yielding low amylose short grain (PR 118) as a non basmati rice and long grain (PUSA 1121) as basmati rice was procured from local seed collection center, Sangrur, Punjab. The paddy was cleaned apparently from the foreign materials using aspirator before the dehusking in laboratory model sheller. The obtained brown rice was milled using rice polisher. The white rice was then subjected to rice grader for head and broken rice separately. The broken rice of both the varieties was grinded in a disk mill. All the equipments used in the process were of Indosaw Industries (P) Ltd., Ambala make. The prepared flour was passed through 100 µm sieve and was used for the rheological experiments.

For viscosity measurement of aqueous rice flour suspension of concentration ranging from 0.5 to 10% (w/w) were placed in a thermostatically controlled water bath maintained at 70 ± 2°C for around 20 minutes for gelatinization of starch. The gelatinized slurry was cooled to 50 ± 2°C and the temperature was maintained with the help of a thermostatically controlled water bath. The rheological measurement was obtained using Brookfield viscometer (RVDV-E 230, Brookfield Engineering Laboratories, USA) at five different rpm (6, 12, 30, 60 and 100) with RV spindles (RV 1-5 type). The spindles were used in accordance with the sample nature to get all the readings within the scale. Before the measurement samples were mixed with the glass rod to form a uniform dispersion.

After the spindles were immersed in the rice flour paste, the measurement were taken 2 min to allow the thermal equilibrium in sample and to eliminate the effect of immediate time dependence. The measurement of the samples were done in triplicates.

Viscosity of sample was determined by calculating the procedure developed by Mitschka (1982). Since, the viscometer does not give direct shear rate and shear stress values, the torque-rpm readings were converted using the procedure followed by Mitschka.The shear rate versus shear stress data were interpreted using equation 1, the power law expression.

$$\tau_i = k\gamma^n \qquad (1)$$

Where, τ_i is shear stress (Nm^{-2}), γ is the shear rate (s^{-1}), n is the flow behavior index and k is the consistency index ($N_n m^{-2}$) .

The method of Mitschka involves taking the measurement as many pairs of torques (α_i) with a spindle for fixed values of rotational speed N_i (rpm). Values of α_i were converted to the shear stress τ_i (Pa) on each of the spindle used by

$$\tau_i = k_{\alpha t}\alpha_i \qquad (2)$$

Where, $k_{\alpha\sigma}$ = shear stress conversion factor and $k_{\alpha\sigma}$ is a function of the spindle number (Mitschka, 1982).

Values of log τ_i were then plotted against log N_i. The slope of this graph is equal to the flow behavior index of the fluid, n. The corresponding values of the shear rate (γ_t) were then calculated using equation 3

$$\gamma_t = k_{N\gamma}(n)N_i \qquad (3)$$

Where, $k_{N\gamma}$ = shear rate conversion factor, min^{-1}.

Values of $k_{N\gamma}$ are a function of the spindle number and the flow behavior index (Table 1).

The conversion factors of 2.35 and 0.449, 0.404, 0.392, 0.387, 0.382 were used for $K_{\alpha t}$ and $K_{N\gamma}$ for spindle no. 1,2,3,4, 5, respectively. Then the apparent viscosity (μ_α) was calculated using Newtonian law

$$\tau_i = \mu_a \gamma_t \qquad (4)$$

Results and Discussions

The flow behavior index (n) of rice flour dispersions for PUSA 1121 and PR 118 varied between 0.47 to 0.88 and 0.46 to 0.76, respectively (Table 1). The value of flow behavior index (n) at low concentrations i.e. from 0.5% to 2% was close to a Newtonian value of 1, which indicated that at low concentration the dispersion behaved marginally as shear thinning (Figure 1). But as the concentration of rice flour was increased from 3% to 10% the flow behavior index value changed from 0.78 to 0.46, decreased values showed non-Newtonian characteristic obeyed by the dispersions. This lower value for rice flour dispersion indicates that they are more pseudo-plastic in nature. Wang *et al.* (2007) observed the similar results for rice flour paste from Chinese variety having concentration levels ranged from 2 to 6%.

The fluid consistency coefficient (k) increased from 1.78 to 99.78 and 1.95 to 83.51 for PUSA 1121 and PR 118, respectivelyon the increase in solid

Table 1. Rheological characteristics of PUSA 1121 and PR 118

Rice Flour Concentration (%)	Flow behaviour Index (n)		Fluid consistency coefficient (k) ($mPa.s^n$)		Apparent viscosity (μ_α) (mPa.s)	
	PUSA 1121	PR 118	PUSA 1121	PR 118	PUSA 1121	PR 118
0.5	0.88	0.76	1.78	1.95	9.6	7.3
1	0.87	0.74	1.2	1.64	11	9
2	0.85	0.70	1.10	1.24	14	11
3	0.78	0.73	3.38	1.89	194	80
4	0.69	0.68	11.78	4.73	340	140
5	0.61	0.57	15.81	14.85	780	510
6	0.56	0.52	21.43	15.53	1200	660
7	0.54	0.51	29.07	29.57	1420	1300
8	0.49	0.49	42.14	33.81	3000	2300
9	0.48	0.47	95.39	65.23	12300	6554
10	0.47	0.46	99.78	83.51	13000	9000

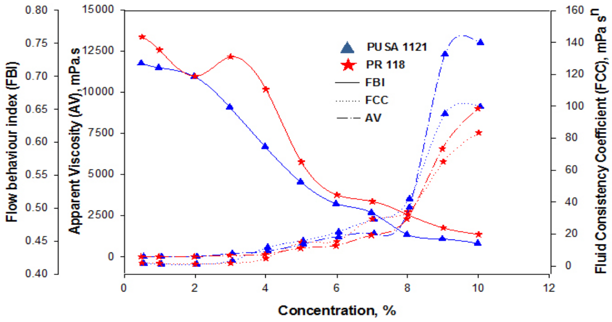

Figure 1. Effect of rice flour concentration on rheological properties

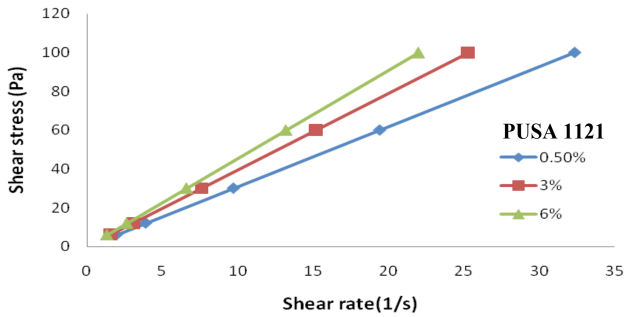

Figure 2. Concentration dependent behavior of shear rate and shear stress for PUSA 1121

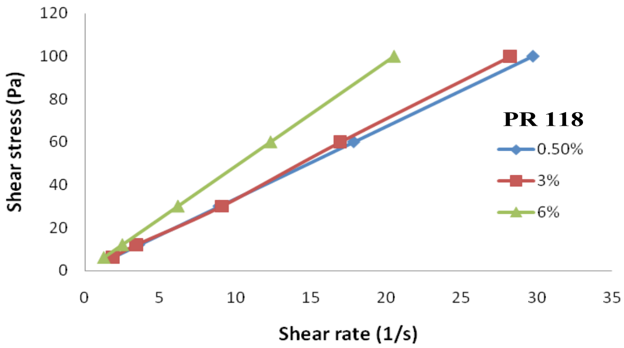

Figure 3. Concentration dependent behavior of shear rate and shear stress for PR 118

concentration (Figure 1). The apparent viscosity also markedly increased as the solid concentration was increased for both the flour types. At low concentration the increase in viscosity was rather low but there was a marked increase as the concentration increased (Figure 1). Apparent viscosity for PUSA 1121 at different shear rate was distinctly higher than the apparent viscosity values for PR 118 (Table 1). This is due to the higher n values for PUSA 1121 than PR 118 variety. Both varieties exhibited a pseudo-plastic behavior (non-Newtonian), as the shear rate increases the viscosity value decreases, highest viscosity was observed at lowest shear rate exhibiting thinning properties.

Time independent deviation from ideal Newtonian behavior will cause the relationship between shear stress and shear rate to be non-linear. The shear rate value increased from 1.78 s^{-1} to 32.33 s^{-1} at 0.5 % and 10% concentrations, respectively with the increase of the RPM of the spindle (Figure 2 and 3). The plot of shear rate versus shear stress of rice flour concentrations from 0.5% to 10% showed that they are non-Newtonian in nature and exhibited pseudo-plastic behavior (Raina *et al*., 2006).

Rheological characteristics of varieties PR 118 and PUSA 1121 were not found the significant differenceat $p \leq 0.05$ and had shown almost similar flow behavior in shear rate, shear stress relationship at all concentration range. From the shear rate, shear stress relationships and flow behavior index, it could be concluded that the rice flour dispersion in the selected concentration range exhibit non-Newtonian behavior.

Conclusion

Rice flour dispersion of PUSA 1121 and PR 118 rice in aqueous dispersion results variations in the rheological characteristics. Increase in rice flour concentration reduces the flow behavior index with the simultaneous considerable increase the fluid consistency coefficient and apparent viscosity following the non-Newtonian flow characteristics.

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