IJFANS
International Journal of Food And Nutritional Sciences

Volume 5, Issue 4, October 2016, www.ijfans.com e-ISSN: 2320-7876

INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES

IMPACT FACTOR ~ 1.021

Official Journal of IIFANS

IJFANS

International Journal of Food and Nutritional Science

e-ISSN 2320 -7876 www.ijfans.com
Vol. 5, No. 4, October 2016

Research Paper *Open Access*

EFFECT OF FINGER MILLET FLOUR ON RHEOLOGICAL PROPERTIES OF WHEAT DOUGH FOR THE PREPARATION OF BREAD

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Received on: 5th May, 2016 Accepted on: 8th July, 2016

The rheological properties of two varieties of wheat flour with finger millet flour were studied using farinograph, extensograph and amylograph. In both the type of mixture the ratio of wheat flour to finger millet flour was 100:0, 95:5, 90:10, 85:15 and 80:20. According to farinogram produced in the system, dough containing 100% wheat flour had highest water absorption, dough stability, degree of softening and farinograph quality number, which went on decreasing as the level of finger millet flour increased in the dough. Dough development time was less for 100% wheat flour dough. Increasing the amount of finger millet flour in wheat dough from 5 to 20%, resulted in decreased resistance to extension and extensibility. However, there was increase in energy, maximum resistance to extension and ratio number which indicated the weakening of dough with increased percentage of finger millet flour. Increase in proofing time also caused the change in the extensibility parameter of the dough. For dough with 100% wheat dough, the beginning of gelatinization was lowest whereas, the gelatinization temperature and the gelatinization peak were highest. The amylographic characteristic was least for the dough with 20% finger millet flour. According to the result obtained from different rheological machine, the changes in the parameter of different treatments was attributed to the lack of gluten in the finger millet flour that caused the dilution of gluten network with the increase in finger millet flour.

Keywords: Finger millet, Wheat, Brabender milling unit, Rheology, Farinograph, Extensograph, Amylograpgh

INTRODUCTION

Finger millet is the staple food of Africa and some parts of India. In India, very small population consumes finger millet in form of porridge, dumpling and *roti*. Finger millet has gained importance because of its nutritional strength. It is a rich source of dietary fiber, calcium and photochemicals with neutraceutical potential (Malleshi and Hadimani, 1994). Some of the health benefits associated with regular intake of millet food is hypocholesterolemic, hypoglycemic and antiulcerative characteristic which indicate the scope for its utilization by the nontraditional millet consumer (Shobana and Malleshi, 2007). Hence, providing the millet similar to rice, wheat or in the form of ready-to-eat convenience cereals would improve its acceptability. Finger millet is cultivated for food, making beer and fodder (Obilana *et al.*, 2002). Foods prepared from finger millet are several and differ from country to country, and occasionally from region to region within a country, such as unleavened bread, thin-or thick porridge, fermented porridge, making “ingera”, etc. (Tsehaye *et al.*, 2006; and Desai *et al.*, 2010).

Fundamental rheological studies can help to show the behavior of dough under small deformations, such as those seen during dough resting and relaxation. It is the study of the flow of materials, or more precisely, the mode of response

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by materials to specific deformation strains or stresses (Steffe, 1996).When a deformation is applied, individual polymers will produce distinct responses to stress or strain, and measuring the differences can provide valuable information about the makeup and structure of that material. Dough rheology is measured under stress and strain, and can be studied as effect of dough ingredients and additives on dough as small deformations. The measurement of rheological properties of dough is complicated and directly affects its processing and the consumer quality. The main aim of rheological measurement is to obtain a quantitative description of the mechanical properties of a material, gain information with relation to the molecular structure and the composition of a material as well as to characterize and simulate the efficiency of a material during the production of quality end product (Dobraszczyk and Morgenstern, 2003).

Among the cereal flours, only wheat flour can form three-dimensional viscoelastic dough when mixed with water. Characterization of rheological properties of dough is effective in predicting the processing behaviour and in controlling the quality of food products. Farinograph, extensograph and amylograph are the most common empirical instruments used for characterizing dough rheology. Tests based on these instruments are useful for providing practical information for the baking industries while they are not sufficient for interpreting the fundamental behaviour of dough processing and baking quality. Farinograph measures specific properties of flour. It was first developed and launched in 1928 in Brabender history, and is the first physical dough testing instrument (Janssen *et al.*, 1996c; and Walker and Hazetton, 1996). It is used to measure the water absorption of flour and does this by mixing the flour and water to produce dough of standard viscosity. It is the reliable and reproducible data about the quality characteristics of flour such as water absorption, dough development time, dough stability, degree of softening and farinograph quality number. Extensograph was developed by Carl Wilhelm Brabender. It measures the stretching properties of the dough in particular the resistance to extension and extensibility, to make reliable statement about the baking behavior of dough. Extensograph shows the influence of flour additives and thus permits to determine the rheological properties of flour. Extensograph is designed to measure the balance of the elastic and viscous properties of dough extension and extensibility of the dough. Amylograph gives information on the gelatinization and the enzyme activity (α-amylase) of flour. It works by measuring the change of viscosity of a flour water paste on heating at uniform rate. As the starch gelatinizes the viscosity increases but the α-amylase present reduces the peak viscosity.

MATERIALS AND METHODS

Sample Preparation

Two varieties of wheat (*Triticum aestivum*), *Tapovan* and *Trimbak*, and finger millet (*Eleusine coracana*) sample, *Phule Nachani* were used. The grains were milled individually in a Brabender Quadrumat Junior flour mill unit. The screen mesh size used for sieving flour was 200 µm. Before milling wheat grains were subjected to tempering and conditioning treatment. Water was added to wheat sample to increase moisture by 3% and conditioned overnight. The conditioned grains were then milled. While in case of finger millet, cleaned grains were soaked in water overnight. They were then washed, steamed for 20 min and dried to 8-12% moisture. The seeds were then conditioned at the rate of 3% and tempered overnight and were milled. This treatment resulted in white finger millet flour as compared to other milling process.

Proximate Composition of Wheat and Finger Millet

The wheat and finger millet was estimated for moisture, protein, carbohydrate, fiber, ash, fat, calcium and iron by the method described in AOAC (1995). Further wheat flour was tested for gluten content and sedimentation value as per the method described by Kent Jones and Amos (1967) and Austin and Ram (1971a), respectively.

Rheological Properties

Rheological properties of dough's were evaluated using farinograph, extensograph and amylograph. Farinograms, extensograms and amylograms were determined according to AACC approved methods No. 54 -21[(1)], 54-10[(2)] and 22-10[(3)] respectively (AACC, 1983).

Farinograph

The instrument consists of a drive unit with continuous speed control and an attached measuring mixer for mixing the dough to be tested. Flour and water suspension is poured into the heated measuring mixer where it is subjected to a defined mechanical stress by the rotating mixer blades. The resistance of the dough against the blades, which depends on the dough viscosity, is measured as torque, recorded and plotted online as a function of time in a clear color diagram recording values of water absorption, dough development time, dough stability, degree of softening, consistency, farinograph quality number. A flour sample of 50 or 300 grams on a 14% moisture basis were weighed and placed into the corresponding farinograph mixing bowl. Water from a burette was added to the flour and mixed to form dough. As the dough was mixed, the farinograph recorded a curve on graph paper. The amount of water added (absorption) which affected the position of the curve on the graph paper. Less water increased dough consistency and moved the curve upward. The curve was centered on the 500-Brabender Unit (BU) line ±20 BU by adding the appropriate amount of water and it was ran until the curve leaves the 500-BU line.

Extensograph

The extensograms recorded online and represented as a color diagram on the monitor, shows the exerted force as a function of the stretching length (time). A 300-gram flour sample on a 14% moisture basis was combined with a salt solution and mixed in the farinograph to form dough. After the dough was rested for 5 minutes, it is mixed to maximum consistency (peak time). A 150-gram sample of prepared dough was placed on the extensograph rounder and shaped into a ball. The ball of dough was removed from the rounder and shaped into a cylinder. The dough cylinder was placed into the extensograph dough cradle, secured with pins, and rested for 45 minutes in a controlled environment. A hook was drawn through the dough, stretching it downwards until it breaks. The extensograph recorded a curve on graph paper as the test was run. The same dough was shaped and stretched at 30, 60 and 90 minutes.

Amylograph

A suspension of flour and distilled water was heated with a constant heating rate of 1.5 °C/min within a rotating bowl. Depending on the viscosity of the suspension, a measuring sensor reaching into the bowl was deflected. This deflection was measured as viscosity over time vs. temperature and recorded on-line.the equipment. A sample of 80 g of flour was combined with 450 ml of distilled water and mixed to make slurry. The slurry was stirred while being heated in the amylograph, beginning at 30 ºC and increasing at a constant rate of 1.5 ºC per minute until the slurry reaches 95 ºC. The amylograph recorded the resistance to stirring as a viscosity curve on graph paper.

RESULTS AND DISCUSSION

The rheological studies were performed with various combination of wheat flour with finger millet flour and results are reported under following headings.

Chemical Composition

The proximate composition of wheat flour plays an important role in deciding its functional qualities. The results obtained for nutritional value of wheat and finger millet flour is presented in Table 1. The moisture content of wheat variety *Tapovan* was 11.83%, while wheat variety *Trimbak* and finger millet variety *Phule Nachani* had 10.50% moisture. *Tapovan* and *Trimbak* variety of wheat cultivars contained 68.43% and 71.68% carbohydrate, respectively. Finger millet contains carbohydrate similar to that of other common cereals. It was observed that variety *Phule Nachani* contained 71.59% carbohydrate. The second major component in cereals is protein. In wheat, protein decides the suitability of wheat for particular type of end use. The result indicated that protein content of wheat flour was 12.50% and 12.63% for *Tapovan* and *Trimbak*, respectively. In general, wheat cultivars having protein content above 12% were considered suitable for bread making (Anonymous, 2002). Therefore, both the wheat varieties are suitable for bread making. The protein content of *Phule Nachani* was 6.33%. The fat content of *Tapovan* and

Table 1: Composition of Wheat and Finger Millet Flour

Proximate Composition	Wheat Varieties		Ragi Variety
	Tapovan	*Trimbak*	*Phule Nachani*
Moisture (%)	11.83	10.5	10.5
Carbohydrate (%)	68.43	71.68	71.59
Protein (%)	12.5	12.63	6.33
Fat (%)	1.82	1.64	1.08
Crude fiber (%)	1.39	1.64	3.15
Ash (%)	1.26	1.33	2.07
Iron (mg %)	3.29	3.37	6.6
Calcium (mg %)	28.21	28.46	284.33
Wet gluten (%)	31.73	32.45	-
Dry gluten (%)	9.56	10.9	-
Sedimentation value (ml)	38.5	40.67	-

Trimbak during the investigation was found to be 1.82 and 1.64% respectively while the fat content of finger millet flour was found to be 1.08%. Crude fiber content of wheat variety *Tapovan* was 1.39% and *Trimbak* was 1.64% but Finger millet was found to contain 3.15% crude fiber which was quite higher than wheat. The ash content of wheat is chiefly composed of phosphorus, calcium, iron and potassium. In present investigation, *Tapovan* had 1.26% ash whereas *Trimbak* recorded 1.33% ash. Ash content of finger millet variety *Phule Nachani* was found to be 2.07%. Calcium content of wheat varieties *Tapovan* and *Trimbak* were 28.21 and 28.46 mg/100 g respectively but the calcium content of finger millet flour was much higher than that of wheat flour (284.33 mg/100 g). It was found that wheat varieties *Tapovan* contained 3.29 mg/100 g and *Trimbak* contained 3.37 mg/ 100 g of iron while millet variety *Phule Nachani* contained 6.6 mg/100 g iron.

Gluten is primarily water insoluble protein of wheat flour. The wet gluten content for *Tapovan* and *Trimbak* was 31.73 and 32.45% respectively, whereas the dry gluten content for wheat cultivar *Tapovan* and *Trimbak* were 9.56 and 10.9% respectively. The sedimentation value is based on the fact that gluten protein absorbs water and swells completely when treated with lactic acid. The sedimentation value for flour of *Tapovan* and *Trimbak* was found to be 38.5 ml and 40.67 ml respectively. The sedimentation values reported in present investigation were 38.5 ml for *Tapovan* and 40.67 for *Trimbak* (near to 40 ml) and hence, both the varieties can be used for bread making.

Rheological Properties

Farinograph Characteristic

The effect of replacement of wheat flour with finger millet flour at 5%, 10%, 15% and 20% level on dough mixing properties was measured by farinograph and results are reported in Table 2. It was observed that there was inverse relation of water absorption and addition of finger millet flour which might be due to dilution of wheat gluten that increases with the addition of finger millet flour.

With the increased level of finger millet flour from 5% to 20%, there was an increase in dough development time from 2.77 min to 3.8 min in *Tapovan*, and from 2.47 min to 3.8 min in *Trimbak*. Dough stability, which is an index of dough strength, was found to decrease with increase in level of finger millet flour in the blend for both the wheat cultivars. The degree of softening, which denotes the elastic proportion of dough followed a different pattern. Degree of softening was lowest for control treatment of *Tapovan* and *Trimbak* varieties, which were 185.33 FU and 179.33 FU respectively. It went on decreasing as the level of finger millet flour increased from 5 to 20%. Farinograph quality number indicates the flour quality. Higher the farinograph quality number, stronger the wheat flour and vice versa. Farinograph quality number decreased from control to treatment T_4. Control of *Tapovan* and *Trimbak* had highest farinograph quality number, 95.67 and 91.67, respectively while the lowest was observed in T_4 treatment of *Tapovan* and *Trimbak*.

Wheat flour exhibited high water absorption, dough development time and dough stability which decreased with the addition of finger millet flour substitution. Shah *et al.* (2011) observed similar farinographic characteristic in their observations on influence of finger millet variety on dough rheology. Lorenz and Dilsaver (1980) have also reported a decrease in water absorption in wheat and proso millet blend. Carson and Sun (2000) also reported that the water

Table 2: Farinographic Characteristic for the Wheat Fortified with Finger Millet Flour

Treatment	Water Absorption (%)		Dough Development Time (Min)		Dough Stability (Min)		Degree of Softening (FU)		Farinograph Quality Number	
	Tapovan	*Trimbak*	*Tapovan*	*Trimbak*	*Tapovan*	*Trimbak*	*Tapovan*	*Timbak*	*Tapovan*	*Trimbak*
T_0	66.5	67.13	2.57	2.4	5.5	4.1	185.33	179.33	95.67	91.67
T_1	66.1	66.7	2.77	2.47	3.2	3.32	157.67	164.33	67.67	77.33
T_2	65.7	66.27	2.9	2.73	2.63	2.73	128	148	66.33	56.33
T_3	65.57	65.77	3.47	3.57	2.17	2.06	99.67	121.67	56	37
T_4	64.87	65.4	3.8	3.8	2.27	1.77	67.33	71.33	39.67	29.33
SE±	0.0325		0.025		0.054		1.47		0.738	
CD at 5%	0.097		0.073		0.161		4.369		2.191	

absorption capacity and dough stability of the composite flour decreased significantly with the increase in the level of sorghum. There was weakening of dough, due to the addition of sorghum, which could be due to decreased wheat gluten content (dilution effect) and competition between the proteins of sorghum and wheat flour for water (Deshpande *et al.*, 1983; and Rao and Rao, 1997).

Extensograph Characteristic

Extensograph data reveals information about the viscoelastic behavior of a dough and measure dough extensibility and resistance to extension. A combination of good resistance and good extensibility results in desirable dough properties (Rosell *et al.*, 2001).

Area under curve or energy, which indicates the dough strength, was similar (44.00 cm^2) for both the control sample at 30 minute of proofing (Table 3). The decrease in value of area under the curve value was observed to increase in finger millet level at 30, 60 and 90 min. Time analysis showed that the energy gradually increased with the increase in proofing time from 30 to 60 and 90 min. The decrease in energy value (cm^2) on addition of finger millet flour might be due to reduced gluten content in T_4 treatment of both the wheat varieties.

It was observed that resistance to extension (Table 4) decreased with the increase in finger millet flour incorporation. Resistance to extension increased with time behaviour at 30, 60 and 90 min. of time analysis.

Table 3: Effect of Different Blends of Wheat and Finger Millet Flour on Energy (cm^2)

Treatment	Proofing Time					
	30 min		60 min		90 min	
	Tapovan	*Trimbak*	*Tapovan*	*Trimbak*	*Tapovan*	*Trimbak*
T_0	44	44	55.33	62	73	71.33
T_1	42.67	40.33	53	56.33	64.33	61.33
T_2	41.67	36.67	50	50.67	60	59.33
T_3	40.67	34	48.67	48	58	56.67
T_4	40	32	45	46.67	55.67	50
SE±	0.362		0.4667		0.2943	
CD at 5%	1.0753		1.385		0.8743	

Table 4: Effect of Different Blends of Wheat and Finger Millet Flour on Resistance to Extensibilition (mm)

Treatment	Proofing Time					
	30 min		60 min		90 min	
	Tapovan	*Trimbak*	*Tapovan*	*Trimbak*	*Tapovan*	*Trimbak*
T_0	146	146.33	180	195	188.67	217
T_1	129.33	137	170.67	180	180	199.33
T_2	118.33	130.67	159.67	166.33	176.67	193.33
T_3	101.33	110.33	141.67	140.33	169.67	170
T_4	89.33	95	125.33	127.67	151.67	156
SE±	0.6699		1.1556		1.4166	
CD at 5%	1.9898		3.4321		4.207	

Here the weakening of dough can be explained as dilution of gluten as well as the presence of high dietary fiber in finger millet and thus, making it more difficult to form a gluten network that attributed to the dough of higher resistance. Extensibility also decreased as the level of finger millet flour blend in wheat flour dough increased (Table5). The extensibility at 30, 60 and 90 min. showed different behaviour. It was observed that from 30 min. to 60 min., there was increase in extensibility which gradually decreased at 90 min. The results are in agreement with Saha *et al.*, (2011) who reported varietal influence of finger millet on rheological properties of flour composite containing 60:40 and 70:30 (w/w) finger millet: wheat flour.

Maximum resistance to extension was significantly influenced by the addition of finger millet in the wheat flour (Table 6). It was also observed that maximum to resistance went on increasing with the time behavior Maximum to resistance had similar behavior as resistance to extension and both these characteristics are highly dependent on the protein content of the flour.

Ratio number is the ratio between resistance to extension and extensibility. It was observed (Table 7) during the study that ratio number significantly increased with the increase in finger millet flour incorporation. A similar behavior occurred with respect to proofing times, where smaller differences occurred between the times. Rosell *et al.* (2001), while evaluating the rheological

Table 5: Effect of Different Blends of Wheat and Finger Millet Flour on Extensibility (mm)

Treatment	Proofing Time					
	30 min		60 min		90 min	
	Tapovan	*Trimbak*	*Tapovan*	*Trimbak*	*Tapovan*	*Trimbak*
T_0	170.33	164.67	186.67	185	173.67	146
T_1	156	147	170.67	168	168.33	134
T_2	148.33	125.33	166	152	150	127
T_3	135	119.33	148.33	140	130	121
T_4	129.33	106.67	127	125	155.33	113
SE±	1.0209		0.6394		1.1718	
CD at 5%	3.03189		1.899		3.4803	

Table 6: Effect of Different Blends of Wheat and Finger Millet Flour on Maximum (BU)

Treatment	Proofing Time					
	30 min		60 min		90 min	
	Tapovan	*Trimbak*	*Tapovan*	*Trimbak*	*Tapovan*	*Trimbak*
T_0	153	157.33	174	205.67	200.33	218.33
T_1	169.33	177.33	192.33	212	217.33	236.67
T_2	171.33	184.67	215.67	245	225.33	253.67
T_3	199	218.67	254	258	274.33	277
T_4	193	196.33	240.67	247	251	263.67
SE±	1.6398		1.935		1.256	
CD at 5%	4.8699		5.7468		3.7304	

Table 7: Effect of Different Blends of Wheat and Finger Millet Flour on Ratio Number

Treatment	Proofing Time					
	30 min		60 min		90 min	
	Tapovan	*Trimbak*	*Tapovan*	*Trimbak*	*Tapovan*	*Trimbak*
T_0	0.87	1	0.93	1	1.1	1.47
T_1	0.9	1.17	1.13	1.3	1.17	1.53
T_2	1.1	1.3	1.17	1.33	1.27	1.6
T_3	1.17	1.37	1.3	1.43	1.43	1.67
T_4	1.3	1.43	1.37	1.57	1.43	1.73
SE±	0.0105		0.1247		0.019	
CD at 5%	0.0313		0.037		0.057	

Table 8: Amylographic Characteristic of Wheat Flour Fortified with Finger Millet

Treatment	Beginning of Gelatinization (?C)		Gelatinization Temperature (?C)		Gelatinization Peak (AU)	
	Tapovan	*Trimbak*	*Tapovan*	*Trimbak*	*Tapovan*	*Trimbak*
T_0	60.3	59.57	94.23	93.87	1844.67	1813
T_1	60.7	61.83	93.87	91.93	1762.33	1790
T_2	61.1	62.23	93.17	91.53	1669.33	1726.33
T_3	61.5	62.7	92.13	90.67	1575.33	1693
T_4	61.83	63.17	90.63	89.5	1432.33	1607.33
SE±	0.06		0.096		3.631	
CD at 5%	0.179		0.285		10.783	

characteristics and quality of bread, also found lower values for the control sample.

Amylograph Characteristic

Amylograph reading for wheat varieties, *Tapovan* and *Trimbak* along with their combinations with finger millet flour are presented in Table 8. Beginning of gelatinization temperature of control was lowest and as the percentage of finger millet incorporation increased from 5 to 20%, the beginning of gelatinization temperature also increased. Gelatinization temperature gradually decreased with the increase in level of finger millet flour. Gelatinization peak for the control of *Tapovan* and *Trimbak* were 1844.67 AU and 1813 AU respectively. It was observed that as the level of finger millet increased from 5 to 20%, the gelatinization peak decreased from 1762.33 AU to 1432.33 AU in *Tapovan* and, from 1790 AU to 1607.33 AU in *Trimbak*. The effect of temperature on dough rheological properties was mainly due to the effect of temperature on gluten rheological properties as resistance to mixing increases in heated gluten (Anusooya *et al.*, 2010). Starch gelatinization is a process that breaks down the intermolecular bonds of starch molecules in presence of water and heat, resulting in exposure of hydrogen bonds (the hydroxyl hydrogen and oxygen) which eventually leads more absorption of water. The gelatinization temperature of starch depends on the amount of water present during gelatinization.

CONCLUSION

The increased level of finger millet to wheat flour showed negative impact on rheological properties. The farinograph properties depended on the finger millet flour portions in mixtures. The increase of the amount of finger millet flour resulted in increase in dough development time along with lower water absorption and dough stability which was due to weakening of the protein network. Extensibility and resistance to extension decreased as the level of finger millet flour increased in the sample. In amylographic properties gelatinization peak and gelatinization maximum decreased on the increased addition of finger millet. Therefore, the addition of finger millet flour to wheat dough seems to produce inferior result but its addition up to 10% is acceptable in bread preparation without further addition of gluten as additive.

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