International Journal of Agriculture Sciences, ISSN: 0975-3710, Volume 1, Issue 2, 2009, pp-46-54

Formulation and characterization of *Millet* flour blend incorporated composite flour

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Abstract- The composite flour containing kodo (*Paspalum Scrobiculatum*) and barnyard *Millet* (*Echinochloa colona*) flour, whole wheat flour and defatted soy flour of four different combinations was prepared and studied the impact of *Millet* flour blend incorporation on characteristics of composite flour. The *Millet* flour blend and composite flour were analyzed for its particle size distribution, sedimentation value, falling number, wet and dry gluten content, bulk density, water absorption capacity (WAC), oil absorption capacity (OAC), swelling power (SP), thermal properties, pasting properties, retrogradation properties (level of syneresis) and chemical parameters such as moisture content, total carbohydrate, crude fiber, protein, fat, starch, amylose, amylopectin and reducing sugar content using standard procedures. Results indicated that wet and dry gluten content, bulk density, WAC, SP decreased significantly ($p<0.05$); level of syneresis and OAC, conclusion gelatinization temperature, gelatinization range (R), protein and crude fiber content were increased significantly at $p<0.05$ with increased proportion of *Millet* flour blend. Due to lower peak viscosity of *Millet* flour blend, the peak viscosities of all composite flour containing *Millet* flour blend were low, compared to the standard composite flour. The setback viscosity was increased with increased proportion of *Millet* flour blend. Thus the analyzed properties of composite flour were significantly modified while increasing the level of incorporation of *Millet* flour blend.
Key words- Composite flour, *Millet* flour blend, Properties, Soy flour, Viscosity

Introduction

Rapid urbanization involving changes in occupation patterns, life styles, family structures and value system are reflected as changes in practices and in the level of physical activity. A large shift from consumption of coarse grains such as sorghum, barley, rye, maize and *Millet* to more refined cereals, like polished rice and wheat is seen especially among the urban population and higher income groups. These changes could result in a significant decrease in the overall fiber content of the diet [1] and associated with rising affluence induced by developmental transition contributed to increasing prevalence of overweight/obesity [2]. One viable strategy for improving public health is appropriate modification of the food supply to give products that deliver substantiated health benefits while retaining consumer appeal. Cereals are prime targets in this regard. As dietary staples, relatively small improvements in grain composition (especially in starch and fiber) have the potential to translate into significant health gains at the population level when they are incorporated into food [3]. Coarse cereals can provide viable alternatives to diversify sources of health components in foods. Obviously, the benefits are highest for whole grain cereal consumption [4]. Although millets are nutritionally superior to cereals, yet their utilization in the country is not widespread. They are mostly used in preparation of traditional dishes. One possible way of extending their utilization could be by blending them with wheat flour after suitable processing. On addition of *Millet* flour to wheat flour or other flours, there would be changes in physico-chemical, nutritional and functional characteristics of wheat flour. Such information will be useful to food processors and nutritionists to formulate commercial products based on wheat-*Millet* blends. Hence the present study was done with the objective to expand the utility of kodo and barnyard *Millet* by value addition through composite flour preparation and its characterization.

Materials and Methods

Materials

Millet flour blend

The present study was done by selecting two minor millets viz., barnyard (*Echinochloa colona*) and kodo *Millet* (*Paspalum Scrobiculatum*), which are rich in fiber and polyphenol among minor millets. Among the cultivated varieties, popular varieties of CO3 of kodo *Millet* and CO1 of barnyard *Millet* were procured from the local market in Salem District, Tamil Nadu, India.The raw grains of kodo and barnyard *Millet* were cleaned, winnowed and soaked in water for 24 hours. The soaked grains were steamed for 20 minutes, shade dried to moisture content of 10-12 g% and milled into flour. The *Millet* flour blend was prepared by mixing equal proportion of kodo *Millet* flour and barnyard *Millet* flour in equal proportion and sieved through 40 mesh sieve.

Composite flour

The prepared *Millet* flour blend was mixed with branded whole wheat flour by replacing at a level of 0%, 10%, 20% and 30% and keeping the level of defatted soy flour at 10% in all combinations.

Methods

Physical Properties

The particle size distribution in % (standard test sieve method), bulk density in g/ml [5], true density in g/ml [6], porosity in % [7], gluten content in both wet mode and dry mode in g% [8], falling number in sec (Hagberg Falling number test) and sedimentation value in ml (Sedimentation Shaker method) [8] were determined as physical properties.

Functional Properties

Water absorption capacity (WAC) in g/g [9], oil absorption capacity (OAC) in g/g [10], swelling power (SP) in ml/g, foaming capacity in ml and foaming stability in min [11], were the determined functional properties.

Nutritional Composition

The nutritional parameters included the determination of moisture and ash content by AOAC method [12]; total carbohydrate and starch by anthrone method; crude fiber by acid-alkali digestion method; total sugar and reducing sugar by dinitro salicylic acid method; amylose and amylopectin by colorimetric method; protein content by kjeldhal method and fat by soxhlet method [13].

Thermal properties

The onset gelatinization temperature (To in ^{o}C) and time (t0 in min); conclusion gelatinization temperature (Tc in ^{o}C) and time (tc in min), and gelatinization temperature range (R in ^{o}C) were determined [14].

Pasting Properties

Pasting properties were measured using a Rapid Visco Analyzer 4D (Newport Scientific Pty. Ltd., Warriewood, Australia). Flour (3g) was dispersed in 25 ml of distilled water. The rotating speed of paddle was 160 rev/min except for first 10 sec. (960 rev/min). The suspension was equilibrated at 50^{o}C for one min and heated at a rate of 120C/min to 95^{o}C and then held at 95^{o}C for 2.5 min. The sample was then cooled to 500C at a rate of 120C/min and then held for 3 min at 50^{o}C. Parameters recorded were pasting temperature in °C (PT), peak viscosity in cP (PV), hot paste viscosity in cP (HPV) (minimum viscosity at 95^{o}C), cold paste viscosity in cP (CPV) (final viscosity at 50^{o}C), breakdown (BD) (=PV-HPV) and set back viscosity in cP (SB) (=CPV-HPV).

Retrogradation Properties

The syneresis of flour gels was measured by the method of Gill et al. [15]. Flour suspensions (10%, w/v) were heated at 900C for 30 min in a temperature controlled water bath, followed by rapid cooling in an ice water bath to room temperature. The flour samples were stored for 24, 48, 72, 96 and 120 h at 4^{o}C. Syneresis was measured as the amount of water released after centrifugation at 3000 rpm for 10 min.

Results and Discussion

Physical Properties

The particle size distribution of *Millet* flour blend and composite flour after sieving through 40-mesh sieve was determined using different sieves with mesh numbers of 44 (355µ), 52 (300µ), 60 (250 µ), 72 (212 µ), 85 (180 µ), 100 (150 µ), 120 (125 µ), 150 (106 µ), 170 (90 µ) and 200 (75 µ) BSS (British Standard Sieve) unit and results in Fig. (1) reveal that 17.13% of *Millet* flour blend (MB), 4.26% of standard composite flour (SCF), 4.64% of 10% *Millet* flour blend incorporated composite flour (10% MBCF), 5.81% of 20% *Millet* flour blend incorporated composite flour (20% MBCF) and 11.54% of 30% *Millet* flour blend incorporated composite flour (30% MBCF) had particle size greater than 60 mesh (BSS). The percentage of fine flour particles was reduced while increasing the percentage incorporation of *Millet* flour blend. The coarseness of *Millet* flour could be due to corneous endosperm texture or husk portion of the grain. If the particle size of flour is big, the flour cannot absorb the necessary water and medium particle size increases the water absorption of flour and reduces the dough development time [16]. Results in Table 1 show that the bulk density, true density, porosity, gluten content, falling number, and sedimentation value of composite flour were decreased significantly ($p<0.05$) with increased percentage incorporation of *Millet* flour blend. Auto-oxidative deterioration is the major cause of spoilage in precooked dehydrated foods due to development of rancid flavour [17]. Higher porosity resulted in greater contact with atmospheric oxygen thereby higher rate of auto-oxidation [18]. The decreased porosity of composite flour may be advantageous with respect to auto oxidative deterioration. The falling number and sedimentation value of composite flour decreased significantly with increase in percentage of *Millet* flour blend. Falling number values of >250 seconds are generally acceptable for bread making. Since, the sedimentation value of *Millet* flour blend and composite flour is more than 40 ml; the flours were suitable for the preparation of pasta, chapati, bread and biscuits.

Functional Properties

The WAC, OAC, SP, foaming capacity and stability of composite flour (Table 2) were decreased significantly ($p<0.01$) with increase in level of *Millet* flour blend. A WAC of more than 68% is generally considered suitable for chapati making. The chapatis prepared from flours with WAC less than 60% were stiff and semi-stiff with poor keeping quality [19]. The data on WAC indicate that all flours characterized in the present study were suitable for chapati making. The foam forming capacity and its stability is drastically reduced in composite flour on incorporation of *Millet* flour blend.

Thermal Properties

The onset gelatinization temperature (To) and time (t0); conclusion gelatinization temperature (Tc) and time (tc) increased significantly ($p<0.05$) with increased proportion of *Millet* flour blend. It may be due to higher To and Tc (86.2^{o}C and 98.8^{o}C) respectively for *Millet* flour blend when compared to SCF as control (Table 3).

Brabender viscoamylograph studies on small *Millet* starches revealed that the onset gelatinization temperature ranged from 75.8 to 84.9^{o}C [20]. The onset gelatinization temperature for *Millet* flour blend was marginally closer to these values. Similar observation on gelatinization range (R) was noted by Sajeev and Moorthy [21] that the foxtail *Millet* yielded a higher gelatinization temperature (R) range of 28.4^{o}C (101.8-73.4^{o}C) followed by 17^{o}C for finger *Millet* and for little millet, a lower range of 12^{o}C. Other flours such as kodo millet, proso *Millet* and barnyard *Millet* yield a range around 13^{o}C.

Nutritional Composition

The flour samples contain moisture in the range of 10.4-13.2 g% (Table 4). The present values were close to the moisture content of *Millet* flours (10.01 to 12.17%) reported by Singh et al. [22]. The total carbohydrate, reducing sugar and total sugar content of composite flour decreased and protein, crude fat and fiber content increased significantly ($p<0.05$) with increase in level of *Millet* flour blend. Similar observation was noted by Singh et al [22] while increasing the levels of foxtail *Millet* flour in blends. Similar observations were noted by Premavalli et al. [23] that the use of foxtail *Millet* in blends (or) barnyard *Millet* in formulation of composite flour is expected to increase the concentration of protein, fat and fiber. The amount of amylose in *Millet* flour blend was 43% which causes the increase in percentage of amylose in composite flour on its incorporation. The amylose/amylopectin ratio was also increased in composite flour as the level of *Millet* flour blend increased.

Pasting Properties

The pasting properties of composite flour (Table 5 and Fig. (2)) concluded that peak viscosity, hot paste viscosity, cold paste viscosity, and breakdown viscosity were decreased, whereas the pasting temperature was increased while increasing the level of incorporation of *Millet* flour blend. In accordance with this, the setback per cent, and breakdown ratio per cent decreased and the CPV/HPV increased with incorporation of *Millet* flour blend. The decrease in viscosity leads to an increase in nutrient or caloric dense food per unit volume consumed [24 & 25]. Barnyard *Millet* possessed lower amylograph viscosity, minimum breakdown, and relative breakdown values when compared to the other small millets [20].

Retrogradation Properties

The level of syneresis was high in flour gels of *Millet* flour blend after 120 hours of refrigerated storage (4.7%). The syneresis value of gels from composite flour increased progressively and significantly ($p<0.01$) during storage as well with raising the level of incorporation of *Millet* flour blend (Table 6). Many investigators have demonstrated that retrogradation of gelatinized starch induces the formation of resistant starch and the retrogradation process is essential for resistant starch development [26].

Correlation between characteristics of composite flour

Pearson correlation coefficients (Bivariate correlation) between selected datasets on quality characteristics of composite flour to predict the influence of incorporation of *Millet* flour blend reveal that the bulk density and porosity of composite flour was directly correlated with the water absorption capacity, oil absorption capacity, swelling power, total carbohydrate content, total sugar, reducing sugar, starch, amylose, amylopectin, peak viscosity and cold paste viscosity of the composite flour (significant at $p<0.05$). It is observed that greater the falling number, higher will be the peak viscosity, hot paste viscosity and peak time of composite flour. Similarly Khetarpaul et al. [8] suggested that the greater the falling number, the higher the viscosity and lower the α-amylase activity. The gelatinization temperature range of composite flour was positively ($p<0.05$) correlated with total carbohydrate, amylose/amylopectin ratio and peak pasting temperature of composite flour. It was negatively ($p<0.05$) correlated with hot paste viscosity and peak pasting time of composite flour. Kaur et al. [27] reported a positive correlation of PV (Peak Viscosity) and TV (Trough Viscosity) with To, Tp and ΔHgel and negative with R has been observed through Pearson correlation results ($p<0.01$). The FV (Final Viscosity) was positively correlated with PT, PV, TV and negatively with gelatinization temperature range (R). It is also predicted that peak viscosity of composite flour was directly influenced by bulk density, dry gluten content, falling number, porosity, WAC, OAC, SP, carbohydrate components, amylopectin content (significant at $p<0.05$) and negatively influenced by protein, fiber, ash, fat and amylose/amylopectin ratio of the composite flour. The level of syneresis of composite flour was positively ($p<0.05$) influenced by protein, fiber, ash and fat content of composite flour. Gunaratne and Corke [28] suggested that starch granular swelling and leaching of soluble carbohydrate (mainly amylose) are the main factors that determine the viscosity development during the pasting process.

Conclusion

The incorporation of *Millet* flour blend improved the quality of composite flour in terms of increasing nutrient density, thinner the gruel by lowered viscosity and increase in the level of syneresis which may improve the resistant starch content on storage. Thus the *Millet* flour blend incorporation significantly modified the properties of composite flour in such a way that it was found suitable for the preparation of pasta, crackers, rusk or suji toast, biscuits, chapati etc. and not suitable for bread and cake preparation.

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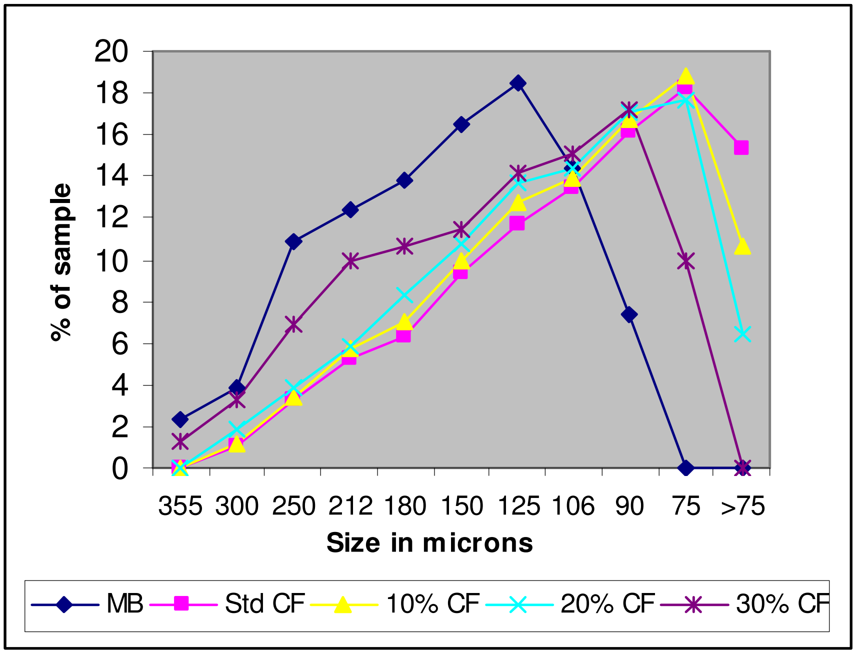

Fig. 1- Particle size distribution of *Millet* flour blend and composite flour

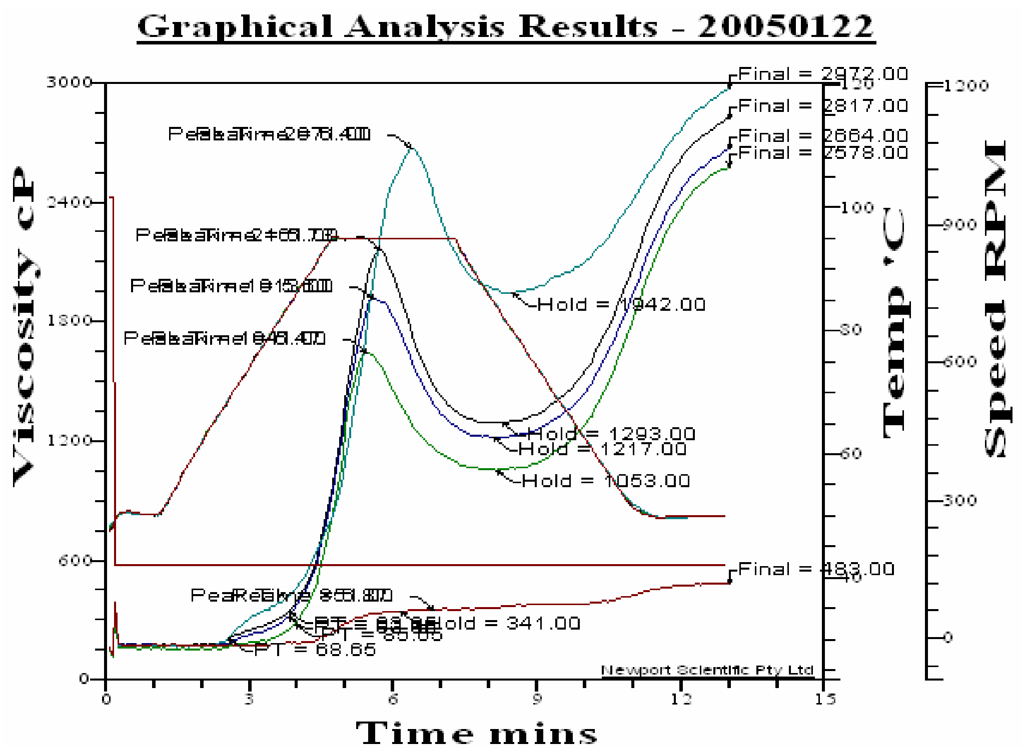

Fig. 2- Pasting properties of *Millet* flour blend and composite flour

Table 1- Physical characteristics of Millet flour blend and composite flour

Physical Characteristics	MB	SCF	10% MBCF	20% MBCF	30% MBCF	CD
Bulk density (g/ml)	0.46±0.0	0.6±0.0	0.58±0.0	0.56±0.0	0.54±0.0	0.04[a] 0.03[b] 0.02[c]
True density (g/ml)	1.97±0.05	2.5±0.0	1.85±0.04	1.43±0.0	1.19±0.02	0.19[a] 0.11[b] 0.07[c]
Porosity (%)	76.6±1.3	76±0.6	68.57±1.5	60.8±1.0	54.5±1.8	8.90[a] 5.22[b] 3.33[c]
Wet gluten content (g %)	0	13.6±0.6	9.4±0.2	8.7±0.1	7.1±0.1	2.12[a] 1.24[b] 0.79[c]
Dry gluten content (g%)	0	4.4±0.2	3.7±0.4	3.1±0.1	2.5±0.2	1.49[a] 0.87[b] 0.56[c]
Falling Number (Sec)	86.5±0.7	338.5±0.7	239.5±0.7	232±0	203.5±0.7	4.34[a] 2.55[b] 1.63[c]
Sedimentation Value (ml)	46.5±0.7	59.5±0.7	56.0±0.0	54.5±0.7	53.0±0.0	3.76[a] 2.21[b] 1.41[c]

MB – *Millet* flour blend, CF – Composite flour, 10% MBCF – 10% *Millet* flour blend incorporated composite flour, 20% MBCF – 20% *Millet* flour blend incorporated composite flour, 30% MBCF – 30% *Millet* flour blend incorporated composite flour; CD – Critical Difference; a - significant at p<0.001, b - significant at p<0.01, c - significant at p<0.05; Values in the table are the average of two determinants.

Table 2- Functional properties of Millet flour blend and composite flour

Functional Properties	MB	SCF	10% MBCF	20% MBCF	30% MBCF	CD
Water absorption capacity (g/g)	0.832±0.01	1.523±0.01	1.489±0.01	1.444±0.01	1.399±0.01	0.95[a] 0.56[b] 0.36[c]
Oil absorption capacity (g/g)	0.682±0.008	0.764±0.001	0.749±0.002	0.733±0.004	0.725±0.002	0.03[a] 0.02[b] 0.01[c]
Swelling power (ml/g)	1.375±0.08	3.165±0.09	2.98±0.27	2.87±0.003	2.715±0.05	0.92[a] 0.54[b] 0.34[c]
Foaming capacity (ml)	3.0±1.41	48.0±4.24	34.5±8.54	26.0±2.83	22.0±2.83	21.4[a] 12.6[b] 8.0[c]
Foaming stability (min)	1.545±0.007	8.145±0.13	3.485±0.09	2.39±0.23	2.095±0.12	0.93[a] 0.55[b] 0.35[c]

MB – *Millet* flour blend, CF – Composite flour, 10% MBCF – 10% *Millet* flour blend incorporated composite flour, 20% MBCF – 20% *Millet* flour blend incorporated composite flour, 30% MBCF – 30% *Millet* flour blend incorporated composite flour; CD – Critical Difference; a - significant at p<0.001, b - significant at p<0.01, c - significant at p<0.05; Values in the table are the average of two determinants.

Table 3- Thermal properties of Millet flour blend and composite flour

Thermal Properties	MB	SCF	10% MBCF	20% MBCF	30% MBCF	CD
Onset gelatinization temperature (^{0}C) T_0	86.2±0.8	81.0±1.3	80.0±1.7	80.8±1.1	81.8±1.2	3.0[a] 2.2[b] 1.6[c]
Conclusion gelatinization temperature (^{0}C) T_C	98.8±0.8	91.14±0.6	91.5±0.9	92.4±0.4	93.6±0.7	1.7[a] 1.2[b] 0.9[c]
Onset gelatinization time (min) t_o	2.0±0.2	1.16±0.04	1.11±0.05	1.08±0.04	1.16±0.1	0.30[a] 0.22[b] 0.16[c]
Conclusion gelatinization time (min) t_c	2.42±0.1	1.58±0.3	1.48±0.1	1.44±0.03	1.47±0.06	0.33[a] 0.24[b] 0.18[c]
% Sag or Gel consistency	7.0±2.3	12.2±6.5	10.3±6.5	10.0±3.8	8.6±3.0	11.6[a] 8.6[b] 6.3[c]
Gelatinization range (T_C-T_0) R (°C)	12.6±0.8	10.14±0.96	11.5±2.2	11.6±1.4	11.8±1.6	3.5[a] 2.7[b] 1.9[c]

MB – *Millet* flour blend, SCF – Standard Composite flour, 10% MBCF – 10% *Millet* flour blend incorporated composite flour, 20% MBCF – 20% *Millet* flour blend incorporated composite flour, 30% MBCF – 30% *Millet* flour blend incorporated composite flour; CD – Critical Difference; a - significant at p<0.001, b - significant at p<0.01, c - significant at p<0.05; Values in the table are the average of two determinants.

Table 4- Nutritional composition of Millet flour blend and composite flour

Nutrients (g%)	MB	SCF	10% MBCF	20% MBCF	30% MBCF	CD
Moisture	10.4±0.42	12.8±0.14	13.2±0.42	13.0±0.27	12.0±0.42	2.6 [a] 1.44 [b] 0.92 [c]
Total carbohydrate	56.8±0.57	64.0±2.83	55.0±2.83	51.0±1.41	48.0±1.41	13.8 [a] 8.13 [b] 5.18 [c]
Protein	14.8±0.42	12.6±0.14	13.8±0.14	14.0±0.14	15.6±0.42	1.99 [a] 1.17 [b] 0.75 [c]
Fiber	6.2±0.14	2.5±0.42	3.9±0.14	4.2±0.28	5.3±0.28	1.89 [a] 1.11 [b] 0.71 [c]
Ash	1.4±0.14	1.6±0.14	1.7±0.28	1.8±0.28	1.8±0.14	1.44 [a] 0.85 [b] 0.54 [c]
Fat	4.4±3.28	3.6±0.14	3.78±0.07	3.9±0.14	4.05±0.06	1.10 [a] 0.65 [b] 0.41 [c]
Total sugar	3.7±0.28	4.5±0.14	4.1±0.14	3.9±0.42	3.6±0.42	1.74 [a] 1.02 [b] 0.65 [c]
Reducing Sugar	0.8±0.14	1.4±0.42	1.1±0.14	0.9±0.14	0.65±0.04	1.51 [a] 0.89 [b] 0.57 [c]
Non-Reducing sugar	2.9±0.42	3.1±0.28	3.0±0.0	3.0±0.0	2.95±0.38	1.96 [a] 1.15 [b] 0.73 [c]
Starch	45.0±1.41	54.6±0.28	48.0±1.41	42.03±0.28	38.46±0.42	6.21 [a] 3.64 [b] 2.32 [c]
Amylose	19.4±0.42	20.3±0.28	19.6±0.42	17.43±0.06	16.26±0.07	2.06 [a] 1.21 [b] 0.77 [c]
Amylopectin	25.6±0.14	34.3±0.42	28.4±0.28	24.6±0.14	22.2±0.28	1.89 [a] 1.11 [b] 0.71 [c]
Amylose/Amylo pectin ratio	0.758±0.01	0.592±0.02	0.690±0.01	0.709±0.0	0.732±0.01	0.08 [a] 0.04 [b] 0.03 [c]

MB – *Millet* flour blend, SCF – Standard Composite flour, 10% MBCF – 10% *Millet* flour blend incorporated composite flour, 20% MBCF – 20% *Millet* flour blend incorporated composite flour, 30% MBCF – 30% *Millet* flour blend incorporated composite flour; CD – Critical Difference; a - significant at p<0.001, b - significant at p<0.01, c - significant at p<0.05; Values in the table are the average of two determinants.

Table 5- Pasting properties of Millet flour blend and composite flour

Pasting Properties	Std Starch	MB	SCF	10% MBCF	20% MBCF	30% MBCF
Peak Viscosity (cP)	4421	1072	2671	2161	1913	1641
Hot Paste Viscosity (cP)	2971	984	1942	1293	1217	1053
Cool paste Viscosity (cP)	4636	2253	2972	2817	2664	2578
Breakdown Viscosity (cP)	1450	88	729	868	696	588
Setback Viscosity (cP)	1665	1269	1030	1524	1447	1525
Breakdown % (BD)	33	8	27	40	36	36
Setback % (SB)	5	110	11	30	39	57
BDr %	87	7	71	57	48	39
Cool paste Viscosity/Hot paste Viscosity	1.56	2.29	1.53	2.18	2.19	2.45
Pasting temperature (^oC)	75.20	87.20	68.65	83.85	83.85	85.65
Peak time (min)	5.07	5.53	6.40	5.73	5.60	5.47

MB – *Millet* flour blend, SCF – Standard Composite flour, 10% MBCF – 10% *Millet* flour blend incorporated composite flour, 20% MBCF – 20% *Millet* flour blend incorporated composite flour, 30% MBCF – 30% *Millet* flour blend incorporated composite flour.

Table 6- Level of syneresis (%) in stored flour gels from Millet flour blend and composite flour

Storage period in hours	MB	SCF	10% MBCF	20% MBCF	30% MBCF	CD
24	1.6±0.11	1.1±0.07	1.2±0.07	1.4±0.07	1.7±0.04	0.51 [a] 0.30 [b] 0.19 [c]
48	2.1±0.07	1.5±0.14	1.8±0.07	2.0±0.07	2.4±0.07	0.57 [a] 0.34 [b] 0.22 [c]
72	2.8±0.14	2.0±0.07	2.4±0.07	2.7±0.14	3.1±0.14	0.81 [a] 0.48 [b] 0.30 [c]
96	3.6±0.07	2.4±0.07	2.8±0.07	3.4±0.07	3.7±0.04	0.45 [a] 0.26 [b] 0.17 [c]
120	4.7±0.11	3.1±0.14	3.7±0.07	4.2±0.07	4.6±0.07	0.66 [a] 0.39 [b] 0.25 [c]
p<0.001 p<0.01 p<0.05	0.70 0.41 0.26	0.72 0.42 0.27	0.43 0.26 0.16	0.61 0.36 0.23	0.55 0.33 0.21	

MB – *Millet* flour blend, SCF – Standard Composite flour, 10% MBCF – 10% *Millet* flour blend incorporated composite flour, 20% MBCF – 20% *Millet* flour blend incorporated composite flour, 30% MBCF – 30% *Millet* flour blend incorporated composite flour; CD – Critical Difference; a - significant at $p<0.001$, b - significant at $p<0.01$, c - significant at $p<0.05$; Values in the table are the average of two determinants.