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A study on functional, pasting and micro-structural characteristics of multigrain mixes for biscuits

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Abstract The four different multigrain mixes were developed by combining whole cereals (barely, sorghum, maize, oats,wheat germ), pulses (chickpea dhal, green gram, peas, soya flour) and millets (finger millet, pearl millet) to get mutual supplementation benefits. The protein content of different mixes ranged from 22.91 to 27.84 % and dietary fiber ranged from 16.82 to 18.72 %. The functional, pasting and micro-structural characteristics of different mixes have been studied to predict its suitability for the preparation of biscuits. The results indicated that the water absorption capacity of these mixes varied from 1.51 to 1.57 g/g, oil absorption capacity varied from 0.84 to 1.03 g/g, water absorption index varied from 3.54 to 3.70 g/g, water solubility index varied from 3.54 to 3.70 g/g, bulk density varied from 0.53 to 0.62 g/ml, peak viscosity varied from 63.83 to 84.79 RVU. Among the different multigrain mixes studied, Mix III had the desired functional characteristics as indicated by its higher water absorption index, water solubility index, bulk density, α-amylase activity and lower alkaline water retention capacity, breakdown viscosity suggesting thereby its suitability for the preparation of biscuits. The biscuit making trials conducted on different multigrain mixes at 20 % level of incorporation have also confirmed that among different multigrain mixes, the multigrain mix III

containing barley, sorghum, chickpea, pea and soya flour gave best quality biscuits.

Introduction

There is an increasing demand for nutritious ready-to-eat foods with better shelf life, at an affordable price and with satisfying taste. The important ready-to-eat products available in the market are mainly from bakery sector [1]. Among the bakery products, biscuits form he most popular snack item as it has several advantages like longer shelf life, availability in varied taste and texture to suit the different cross section of the population [2]. The normal biscuits are prepared from refined wheat flour, which is known for its poor nutritional quality [3]. The awareness to consume high quality and healthy food has increased the demand for functional foods, which contain ingredients that provide additional health benefits beyond the basic nutritional requirements [4]. Therefore, the consumers are looking for products made from whole grains than refined flours as they are rich in fibers, vitamins and minerals.

The different whole grains like barley and oats are known for its excellent sources of soluble and insoluble fibers mainly beta-glucan, which helps to reduce cholesterol level [5]. Millets like finger millet and pearl millet are rich sources of minerals, mainly calcium, iron, zinc and phosphorus apart from a good source of dietary fiber [6]. The wheat germ, a by-product of wheat milling industry is rich in protein, dietary fiber, B-group vitamins and vitamin E [7]. Pulses like chick pea, green gram and pea are a rich

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source of quality and quantity protein, mainly essential amino acids like lysine, arginine, leucine, isoleucine which are limited in other grains [8]. The oil seed like soya is known for its rich protein content with high levels of lysine and other micronutrients [9]. Therefore, combining different whole grains in multigrain mix has an added nutritional advantage of mutual supplementation of amino acids and thereby improving the quality and quantity of protein, dietary fiber in addition to increase in other nutrients like vitamins, minerals etc. needed for all round maintenance and growth [8].

The basic composite flour technology refers to the process of mixing wheat flour with any one or two cereals or legumes to improve the nutritional quality of food products in an economical way [10]. However, these composite flour products are rich in only a few nutrients depending upon the non-wheat flour ingredient used in the mix. None of the composite flour products reported to so far contain all the nutrients in balanced amounts required for overall growth and maintenance of health [11, 12]. On the other hand, in case of multigrain based composite flour, a mixture of several grains is used to get multiple health benefits. In addition, these multiple grains will also improve the functional and sensory properties of the end products [13].

It is well known that functional, pasting and micro-structural characteristics of flour, greatly influence the quality of biscuits [14, 15]. The present study is aimed to develop suitable multigrain mix using different whole grains and to determine the above characteristics to select the best mix, which gives a good quality biscuits.

Materials and methods

The different grains like barley (*Hordeum vulgare L.*), pearl millet (*Pennisetum glaucum*), maize (*Zea mays L.*), oats (*Avena sativa*), sorghum (*Sorghum vulgare*), finger millet (*Eleusine coracana*), chickpea (*Cicer arietinum*),

Mills Pvt. Ltd, Thrissur, Kerala, India. All the grains were cleaned and stored individually in an airtight container.

Formulation of multigrain mixes

All the grains were separately milled in an ultra-centrifugal mill (Retsch ZM 200, Germany) using 200 μm sieve. The four different multigrain mixes containing five ingredients at the level of 20 % were developed (Table 1). These mixes were formulated to get maximum benefit of protein and dietary fiber in all the mixes. These were achieved by combining different types of cereals, pulses, millets in all the mixes.

Chemical composition of multigrain mixes

The moisture (method 44-16), protein (method 46-10), fat (method 30-10), ash (method 08-01) were analyzed based on the AACC (2000) procedures [16]. The total dietary fiber was estimated according to the methods of Asp et al. [17]. The mean of three independent determinations was reported.

Functional property of multigrain mixes

Water absorption capacity (WAC) and oil absorption capacity (OAC)

The WAC and OAC of the mixes were determined according to the method of Sosulski et al. [18] with slight modifications. The one gram sample was suspended in 10 ml of distilled water or refined oil in a centrifuge tube followed by vigorous shaking for 5 min. The samples were kept aside for 30 min, centrifuged at 6000 rpm for 15 min, the supernatant was decanted after 5 min and centrifuge tube was weighed. The experiment was repeated in triplicates and the mean was reported.

$$\text{Water/Oil absorption capacity} = \frac{\text{Wt. of C.T} + \text{Sample} - \text{Wt. of C.T} + \text{Sample after centrifuge}}{\text{Wt. of sample}}$$

whole green gram (*Phaseolus aureus roxb*), whole dry pea (*Pisum sativum*), were procured from the local market in Mysore, Karnataka, India. Defatted toasted soya flour (*Glycine max*) was procured from the Sakthi Soya Company, Pollachi, Tamilnadu, India. Wheat (*Triticum aestivum*) germ was procured from the Yamuna Roller Flour

Water absorption index (WAI) and water solubility index (WSI)

The WAI and WSI of the mixes were determined according to the method of Jaspreet et al. [19]. 2.5 g of the mix was suspended in 30 ml distilled water and mixed using a glass

Table 1 Formulation of Multigrain mix

Mix I[a]	Mix II	Mix III	Mix IV
Oats	Pearl millet	Barley	Pearl millet
Finger millet	Finger millet	Sorghum	Barley
Chickpea dal	Oats	Chickpea dal	Maize
Wheat germ	Green gram	Peas	Green gram
Defatted soya flour	Defatted soya flour	Defatted soya flour	Defatted soya flour

[a] Each grain at 20 % level

rod followed by cooking at 90 °C for 15 min in a water bath. The cooked paste was cooled to room temperature, transferred to centrifuge tubes and centrifuged at $3000 \times g$ for 10 min. WAI and WSI were calculated by using below formula and the mean of three independent determinations was reported.

$$\text{Water Absorption Index} = \frac{\text{Wt. of sediment}}{\text{Wt. of dry solids}}$$

$$\text{Water Solubility Index} = \frac{\text{Wt. of dissolved solids in supernatant}}{\text{Wt. of dry solids X 100}}$$

Bulk density (BD)

The BD of the mixes was determined according to the method described by Okaka and Potter [20]. The 100 gram sample was filled in 100 ml standard flask. The weight of the empty cylinder and sample weight was noted and bulk density was calculated according to below formula and the mean of three independent determinations were reported.

$$\text{Bulk Density (g/ml)} = \frac{\text{Wt. of sample}}{\text{Volume occupied}}$$

Alkaline water retention capacity (AWRC)

The AWRC is the amount of alkaline water held by mix at 14 % moisture basis after centrifugation was determined according to the method (56-10) of AACC (2000) [16]. Analysis was carried out in triplicates.

Determination of α-Amylase activity

The α- amylase activity of the mixes was determined using Falling number (FN) (method 56-81) and RVA stirring number (SN) (Method 22-08) as described by AACC (2000) [16]. The amylase activity of flours is negatively correlated to peak viscosity of starch in the flours [21]. RVA stirring number is expressed as the viscosity at 3.0 min, which is an indication of amylase activity and is highly correlated with falling number. The higher SN

values indicate lower amylase activity. Analysis was carried out in triplicates.

Determination of pasting properties of multigrain mixes

The pasting characteristics of mixes were studied using the Rapid Visco Analyzer (Newport Scientific Pvt. Ltd, Warier Wood, Australia) according to AACC (2000) [16] with modifications. The total program was run for 13 min starting at 50 °C, and heated to 95 °C at a constant rise of 12 °C/min, holding the temperature at 95 °C for 2.5 min and then cooling the system to 50 °C at 12 °C/min for 3 min. The viscosity parameters measured were pasting temperature, peak viscosity, breakdown viscosity, final viscosity and setback viscosity. The mean of three independent determinations was recorded.

Microstructure characteristics of multigrain mixes

The microstructure studies of mixes were carried out using Scanning electron microscope (EVO LS10 SEM, Zeiss, UK) to study the internal structure of mixes. The sample preparation for the study was carried out according to the method of Indrani et al. [8]. All the four mixes were defatted using hexane. The defatted mixes were sputter coated with gold–palladium alloy and the morphological analysis was carried out at high vacuum using an operating voltage of 10 kV.

Biscuit preparation and evaluation

Biscuits were prepared using multigrain mixes according to the AACC (2000) [16] method 10-52. The effect of multigrain mixes on physical and sensory characteristics of biscuits was carried out. Six biscuits at random were taken at a time to measure diameter (D) and thickness (T). Spread ratio was calculated from the ratio of diameter to thickness (D/T). Sensory analysis of biscuits was carried out by a panel of 20 members of age between 25 to 50 years, including both male and female, who had earlier

Table 2 Chemical composition of different grains used in Mulitgrain mix

	Moisture %	Ash %	Total protein %	Total fat %	Total dietary fiber %
Barley	11.8 ± 0.13	1.4 ± 0.11	12.87 ± 0.13	1.51 ± 0.14	16.82 ± 0.23
Sorghum	11.22 ± 0.09	1.81 ± 0.06	10.92 ± 0.09	2.31 ± 0.11	13.76 ± 0.18
Maize	13.31 ± 0.11	1.74 ± 0.13	11.87 ± 0.17	3.87 ± 0.15	12.21 ± 0.11
Oats	10.28 ± 0.17	1.92 ± 11	13.91 ± 0.11	8.35 ± 0.21	17.82 ± 0.21
Wheat germ	6.81 ± 0.17	3.91 ± 0.17	31.28 ± 0.18	8.31 ± 0.13	16.87 ± 0.13
Chickpea dal	9.91 ± 0.13	2.77 ± 0.13	21.13 ± 0.21	6.37 ± 0.16	8.13 ± 0.21
Green gram	10.44 ± 0.04	3.92 ± 0.11	23.87 ± 0.12	1.37 ± 0.22	16.17 ± 0.11
Peas	13.28 ± 0.1	2.55 ± 0.07	20.1 ± 0.11	1.44 ± 0.12	13.06 ± 0.19
Finger millet	12.73 ± 0.12	2.98 ± 0.07	7.87 ± 0.07	1.46 ± 0.11	18.98 ± 0.17
Pearl millet	11.89 ± 0.09	2.68 ± 0.04	11.87 ± 0.21	4.31 ± 0.17	17.28 ± 0.24
Soya flour	7.97 ± 0.12	4.35 ± 0.18	57.81 ± 0.13	1.13 ± 0.11	16.73 ± 0.22

Values are expressed as mean ± SD of the observations from three independent experiments

Table 3 Chemical and Functional properties of Multigrain mix

Parameter	Mix I	Mix II	Mix III	Mix IV
Moisture (%)	7.73 ± 0.06[a]	7.42 ± 0.05[b]	8.13 ± 0.09[c]	7.27 ± 0.06[d]
Ash (%)	3.35 ± 0.1[a]	3.23 ± 0.007[ab]	3.46 ± 0.007[a]	3.11 ± 0.04[b]
Total Protein (%)	27.84 ± 0.24[a]	23.96 ± 0.16[b]	26.28 ± 0.18[c]	22.91 ± 0.22[d]
Total Fat (%)	4.69 ± 0.15[a]	3.49 ± 0.06[b]	3.18 ± 0.18b[c]	2.91 ± 0.16[c]
Total Dietary Fiber (%)	18.72 ± 0.39[a]	18.68 ± 0.22[a]	17.51 ± 0.03[b]	16.82 ± 0.18[c]
WAC (g/g)	1.57 ± 0.02[a]	1.53 ± 0.02a[b]	1.56 ± 0.01[ab]	1.51 ± 0.02[b]
OAC (g/g)	1.03 ± 0.08[a]	0.85 ± 0.06[b]	0.87 ± 0.01[b]	0.84 ± 0.06[ab]
WAI (g/g)	3.54 ± 0.07[a]	3.69 ± 0.17[a]	3.70 ± 0.04[a]	3.58 ± 0.19[a]
WSI (%)	15.37 ± 0.16[a]	14.02 ± 0.41[b]	15.63 ± 0.54[a]	11.87 ± 0.43[c]
Bulk density (g/ml)	0.58 ± 0.01[a]	0.53 ± 0.01a[b]	0.62 ± 0.03[b]	0.61 ± 0.04[b]
AWRC	100.22 ± 0.38[a]	109.65 ± 0.96[b]	104.4 ± 0.97[c]	118.59 ± 0.26[d]

Values are expressed as mean ± SD of the observations from three independent experiments. Mean values in the same row followed by different superscripts among the mixes differ significantly (P ≤ 0.05)

WAI water absorption index, *WSI* water solubility index, *WAC* water absorption capacity, *OAC* oil absorption capacity, *AWRC* alkaline water retention capacity

experience in sensory evaluation of biscuits according to the method of Larmond [22].

Statistical analysis

The results were expressed as mean ± standard deviation. All data were analyzed by one way analysis of variance (ANOVA) as per the method of Steel and Torrie [23].

Results and discussion

Chemical composition of multigrain mixes

The chemical compositions of different grains and multi-grain mixes were presented in Tables 2 and 3 respectively. All the four mixes had a moisture content range from 7.27 of Mix IV to 8.13 % in case of Mix III. The ash contents of the mixes were found to be higher and this is supported by earlier studies carried out by Indrani et al. [8] on multigrain mixes. All the mixes had a high protein ranging from 23.96 to 27.84 % due to the use of protein rich ingredients like soya flour, Bengal gram, green gram, peas, oats, wheat germ etc. The fat content of the mixes varied from 2.9 to 4.6 %. Mix I contained high fat content of 4.6 % may be due to the presence of high fat wheat germ [24]. The total dietary fiber of mixes ranged from 16.82 in Mix IV to 18.72 % in the case of Mix I. This high fiber content of the mixes may be due to the use of whole grains and fiber rich ingredients like wheat germ, finger millet, barley, oats etc.

Functional properties of multigrain mixes

Functional properties of flours play a key role in the quality of bakery products [14]. The WAC is the ability of the mix to absorb water and swell for improved consistency in

food. The WAC of the mixes ranged from 1.51 for Mix IV to 1.57 g/g for Mix I (Table 3). WAC is a critical function of protein, which is known to imbibe water without dissolution of protein, thereby attaining body thickening and viscosity [25]. High WAC of flours in bakery products helps to prevent staling by reducing moisture loss [26]. High WAC is also attributed to lose structure of starch polymers while low value indicates the compactness of the structure [27]. OAC of the mix is equally important, as it improves the mouth feel and retains the flavor. Mix I had the highest OAC of 1.03 g/g than other mixes may be due to the presence of high fat content compared to other mixes. The OAC of the mix is influenced by lipophilicity of protein molecules and the presence of large proportion of hydrophobic groups on the surface of protein [28, 29]. Mix I, having highest OAC could be therefore being better to other mixes as flavor retainer. Seena and Sridhar [30] reported OAC is desired in food formulations to improve the flavor retention, palatability and shelf life extension of baked good, meat products and soups.

WAI measures the volume occupied by the starch granules after swelling in excess water and maintains the integrity of starch in aqueous dispersion. It is also important in bulking and consistency of products, as well as in baking application [31, 32]. Among the mixes, Mix III showed higher WAI and WSI, which is very important in dough development and biscuit quality. The difference in the WAI and WSI of the mixes may be due to the difference in the morphological structure of starch granules of the individual flour used in the mixes [33].

The BD of the mixes varied from 0.53 to 0.62 g/ml and the minimum and maximum was observed in Mix II and III respectively. The highest bulk density in Mix III indicates its finer particle size. Finer particle size of flour is desirable in biscuit production as it enhances the ability of the flours to absorb more water [34]. BD is generally influenced by the particle size and initial moisture content of the flour and plays a key role in determining the packaging requirement, handling of food material and application in wet processing in the food industry [35]. Higher BD of mixes suggests their suitability for use in food preparations, whereas low BD would be an advantage in the formulation of complementary foods [36]. AWRC is a simple index to determine the suitability of flour for biscuit preparation and it has an indirect bearing on the spread of biscuits. There was a significant ($p \leq 0.05$) difference in AWRC of the mixes were observed and it varied from 100.22 to 118.59. Mix I and Mix III had comparatively low AWRC than Mix II and IV; therefore, a good biscuit spread could be expected when using Mix I or III. Earlier, Sathe et al. [37] also reported as the AWRC increases, decreased cookie spread for great northern bean cookies.

Table 4 Amylase activity of Multigrain mixes

Multigrain mix	Falling number (s)	Stirring number (RVU)
Mix I	356.5 ± 2.1^a	73.83 ± 0.3^a
Mix II	306.5 ± 2.1^b	78.29 ± 1.8^b
Mix III	272 ± 2.8^d	63.83 ± 0.9^c
Mix IV	335 ± 2.1^c	73.69 ± 0.6^a

Values are expressed as mean $\pm$ SD of the observations from three independent experiments

Mean values in the same column followed by different superscripts among the mixes differ significantly ($P \leq 0.05$)

RVU rapid visco-analyser unit

α-Amylase activity of multigrain mixes

The α- amylase has a role in the spread factor of biscuits and the same is due to reduction in molecular size of starch to a certain extent to produce a greater spread in biscuits. The flour with high α-amylase activity is preferred for short dough biscuits [38]. The α-amylase activity of multigrain mixes was determined by falling number and stirring number and presented in Table 4. A falling number of above 300 s, indicates minimal α-amylase activity and below 250 s indicates substantial α-amylase activity, whereas, higher the stirring number value lowers the α-amylase activity. The Mix I, II, IV had falling number of 356.5, 306.5 and 335 s respectively, indicating minimal α-amylase activity and Mix III had a lower falling number of 272 s indicating higher amylase activity. The α-amylase activity determined by falling number is supported with RVA stirring number. In which also, Mix I, II, IV had a higher stirring number of 73.83, 78.29, 73.69 RVU respectively, indicating lower α-amylase activity, whereas, Mix III had a lower stirring number of 63.83 RVU, which indicates higher α-amylase activity compared to other mixes. There is a negative correlation between α-amylase activity (determined by both falling number and stirring number) and peak viscosity of pasting properties were observed. Earlier, Noda et al. [39] reported the negative correlation between amylase activity and peak viscosity in wheat grains damaged by α-amylase. The optimum level of enzyme activity is ultimately governed by the end use of the flour and the type of processing involved as mentioned by Mailhot and Patton [40].

Pasting properties of multigrain mixes

The pasting properties of multigrain mixes were measured using RVA under controlled condition of heating, holding and cooling. Pasting properties play an important role in quality and aesthetic considerations in the food industry since they affect the texture and digestibility as well as the end use of starch based food commodities [35, 41]. The

Table 5 Pasting properties of Multigrain mixes

Multigrain mix	Pasting temperature (°C)	Peak viscosity (RVU)	Breakdown viscosity (RVU)	Final viscosity (RVU)	Setback viscosity (RVU)
Mix I	85.08 ± 0.8^a	75.92 ± 0.3^a	9.21 ± 0.2^a	126.39 ± 2.4^a	55.59 ± 0.9^a
Mix II	83.08 ± 1.1^a	84.79 ± 0.2^b	21.29 ± 0.4^b	176.75 ± 2.2^b	113.25 ± 1.5^b
Mix III	82.25 ± 1.2^a	68.00 ± 0.3^c	3.59 ± 0.2^c	115.08 ± 2.8^c	48.96 ± 2.8^c
Mix IV	83.925 ± 2.3^a	63.83 ± 0.7^d	15.14 ± 0.04^d	149.63 ± 0.6^d	101.21 ± 1.7^d

Values are expressed as mean $\pm$ SD of the observations from three independent experiments

Mean values in the same column followed by different superscripts among the mixes differ significantly ($P \leq 0.05$)
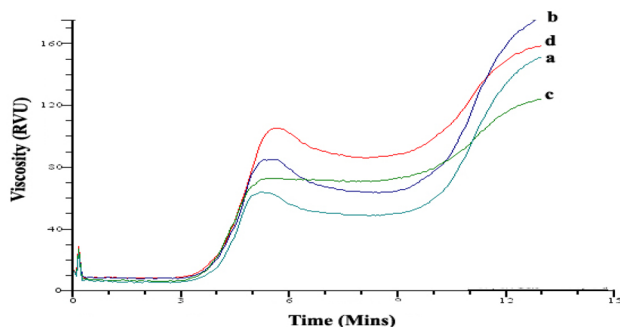
RVU Rapid visco-analyser unit

Fig. 1 typical RVA curve for pasting properties of multigrain mixes. *a* Mix I; *b* Mix II; *c* Mix III; *d* Mix I

results of pasting properties of multigrain mixes were represented in Table 5 and Fig. 1. The pasting temperature, which is the measure of onset of the rise in viscosity or minimum temperature required for cooking. There was no significant difference (p ≤ 0.05) in pasting temperature and it ranged from 82.25 to 85.08 °C. Schoch and Maywald [42] reported that higher fat and protein contents influence the swelling power and pasting properties of starches. Peak viscosity, is the capacity of the starch to swell freely before their physical breakdown, and was ranged between 63.83 and 84.79 RVU. The multigrain mix II had highest peak viscosity of 84.79 RVU indicating high starch content, which is suitable to produce products of high gel strength and elasticity compared to Mix I, III and IV [43]. The mix IV had a lower peak viscosity of 63.83 RVU, thus lower gas retention and lower expansion of the product could be expected. The Mix II had a highest breakdown viscosity of 21.29 RVU, whereas, Mix III had a lowest breakdown viscosity of 3.59 RVU. The higher the breakdown viscosity lowers the ability of the starch sample to withstand heat and shear stress during cooking [44]. Therefore, Mix III will withstand more heating and shear stress compared to other mixes. The final viscosity of the different mixes was ranged from 115.08 RVU of Mix III to 176.75 RVU of Mix II. Final viscosity gives an idea of

ability of starches to form a gel after cooking. The highest final viscosity of Mix II could be due to higher reassociation of amylase molecules. Setback viscosity is a measure of recrystallization of gelatinized starch during cooling. The Mix II had a highest setback viscosity (113.25 RVU) followed by Mix IV (101.21 RVU), Mix I (55.59 RVU) and Mix III (48.96 RVU), thereby indicating higher retro-gradation of starches while cooling in Mix II. The higher the setback viscosity the lower the retrogradation of the mixes during cooling and the lower the staling rate of the product made from this mix [45].

Microstructure of multigrain mixes

Figure 2, represents the micrographs of MGPs. This micrograph clearly shows the small and large starch granules and aggregation of protein bodies, protein matrix and fibrous structure of multigrain mixes. Earlier, Rojas et al. [46] also reported the similar large and small starch granules and aggregation of the protein matrix in the microstructure of wheat flour. The starch granules adhering to protein bodies can be observed. The more number of protein bodies and its aggregates can be seen in the micrographs due to the presence of protein rich legumes like soya flours, oats, chickpea, green gram and pea in MGPs [47]. The fibrous structure of insoluble dietary fiber can be clearly seen in all the MGPs which may be due to the use of fiber rich ingredients like oats, barley, wheat germ, finger millet in the formulations. These fibrous structures are innumerable coil typed structure with an uneven surface. Similar types of fibrous structure are reported by Sowbhagya et al. [48] on their study on micro-structural characteristics of celery seed spent residue added biscuits.

Evaluation of biscuits

Physical and sensory properties of biscuits are the most used parameter to assess the effect of the addition of non-
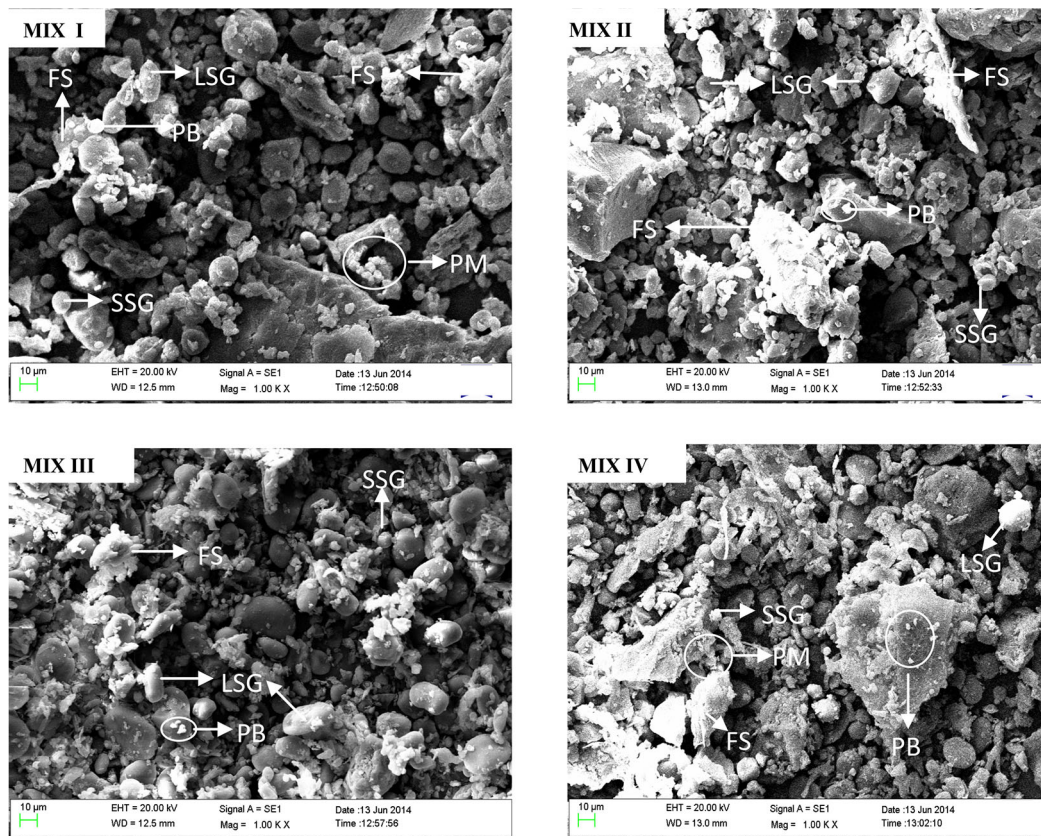
Fig. 2 Microstructural Study of Multigrain mixes. *SSG* small starch granules, *LSG* large starch granules, *PM* protein matrix, *PB* protein bodies, *FS* fibrous structure

wheat flour on quality of biscuits [49]. Table 6 shows the effect replacement of wheat flour with multigrain mixes at 20 % level on physical and sensory characteristics of biscuits. The addition of multigrain mix significantly decreased the diameter of the biscuits and increased the thickness of the biscuits. The minimum change in diameter and thickness was observed with Mix III, followed by Mix I and attributed to its low AWRC [37]. The spread ratio of biscuits decreased from 10.11 for control biscuit to 9.91, 9.54, 10.05, and 9.33 for Mix I, II, III and IV respectively. Similar observation of decreased spread ratio of biscuits by the addition of wheat bran was reported by Sudha et al. [50]. Earlier, Fuhr [51] reported that replacement of wheat flour by non wheat flours, which absorbs more water during dough development, decreases the spread ratio.

Multigrain mix significantly decreased the sensory characteristics of biscuits. The control biscuit was in golden brown in color with smooth surface and crisp texture. All the four mixes significantly decreased the crust and crumb color of biscuit due to the presence of dark colored ingredients in the multigrain mix. The crumb texture indicates the hardness of the biscuits also increased. The maximum increase in hardness was

observed with Mix I as showed by its very low score of 7.28. The increased hardness in biscuits prepared from Mix I may be due to the presence of high fiber content and presence of wheat germ. Metwal et al. [52] reported that the sensory properties of cookies were affected by the addition of debittered fenugreek and flax seed powder at 20 % level and above. Biscuit from Mix III showed very crispy texture due to its increased spread and which is comparable to that of control biscuits. The taste and mouth feel of biscuits prepared from Mix III was highly acceptable than other biscuits as indicated by its high score. These biscuits had the typical flavor of multigrain and comparatively less dry mouthfeel than other biscuits. The OAA of biscuits indicated that biscuits prepared from Mix III, produced highly acceptable quality biscuits with improved taste and flavor than other mixes.

Conclusions

An attempt has been made to develop a suitable multigrain mix for biscuits by combining different whole cereal, pulses and millets. These mixes were found suitable to improve the nutritional quality of biscuits, due to its high

Table 6 Physical and sensory properties of biscuits

	Diameter (mm)	Thickness (mm)	SR	Crust colour	Crumb colour	Crumb texture	Taste	Mouthfeel	OAA
Control	57.61 ± 0.32^a	5.69 ± 0.13^b	10.11 ± 0.19^a	8.35 ± 0.16^a	8.2 ± 0.14^a	8.27 ± 0.21^a	7.97 ± 0.16^a	8.13 ± 0.29^a	8.05 ± 0.08^a
Mix I	57.38 ± 0.26^a	5.78 ± 0.20^b	9.94 ± 0.35^a	7.69 ± 0.19^c	7.83 ± 0.26^b	7.28 ± 0.23^d	7.41 ± 0.25^b	7.87 ± 0.16^b	7.47 ± 0.18^c
Mix II	55.88 ± 0.41^b	5.86 ± 0.08^{ab}	9.54 ± 0.14^b	7.73 ± 0.23^c	7.64 ± 0.20^b	7.6 ± 0.22^c	7.61 ± 0.22^b	7.66 ± 0.19^b	7.72 ± 0.17^b
Mix III	57.41 ± 0.30^a	5.71 ± 0.11^b	10.05 ± 0.21^a	8.01 ± 0.18^b	8.11 ± 0.17^a	8.04 ± 0.27^{ab}	8.00 ± 0.17^a	8.11 ± 0.10^a	8.03 ± 0.14^a
Mix IV	55.87 ± 0.27^b	5.99 ± 0.12^a	9.33 ± 0.17^b	7.63 ± 0.14^c	7.72 ± 0.21^b	7.86 ± 0.23^{bc}	7.91 ± 0.20^a	7.73 ± 0.16^b	7.76 ± 0.10^b

Values are expressed as mean $\pm$ SD. Mean values in the same column followed by different superscripts among the mixes differ significantly ($P \leq 0.05$)

SR spread ratio, OAA over all acceptability

protein, dietary fiber and mineral contents. The various functional, pasting characteristics of different multigrain mixes have been studied to predict its suitability for biscuits. Among different mixes, Mix III was found to be suitable for the preparation of biscuits as it had a higher water absorption index, water solubility index, bulk density, α-amylase activity and lower alkaline water retention capacity, breakdown viscosity which are desirable to obtain a good quality biscuits. The above results also substantiated by biscuit making trials, as the biscuits made from Mix III gave a good quality biscuit among the other mixes as indicated by sensory attributes. Therefore, various functional attributes as well as biscuit making trials showed clearly that the multigrain mix III containing barley, sorghum, chickpea, pea and soya flour were found to be quite suitable for biscuit making.

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