Physicochemical composition and glycemic index of whole grain bread produced from composite flours of quality protein maize and wheat

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Summary

This study entails quality assessment of whole grain bread produced from composite flours of quality protein maize and wheat. Quality protein maize and wheat were processed into flours and mixed at various ratios for bread production. The proximate compositions, physical properties, glycemic response, functional and sensory properties of the samples were evaluated using standard methods. The result showed no significant difference ($p<0.05$) in the proximate composition parameters of the bread samples. The loaf height (2.50 - 3.95 cm), volume (291.00 - 415.00 cm^3) and specific volume(1.72 - 2.42 cm^3/g) decreased significantly with increasing level of quality protein maize, however, loaf length was not affected by the substitution of quality protein maize. The result of the functional properties showed that final viscosity, water absorption and swelling capacity increased with increasing level of quality protein maize. The result of the glycemic response showed that the inclusion of quality protein maize resulted in decline in the blood glucose content (glycemic index) of the products. The bread samples were generally acceptable however; bread with 100% wheat was the most preferred. The result of the sensory properties showed that there was significant difference ($p<0.05$) in the texture and taste of 100% wheat bread and the other samples. The study concluded that substitution of quality protein maize with wheat produced acceptable whole grain loaves that have positive effect on the reduction of blood glucose level.

Keywords: quality protein maize, bread volume, dough expansion, bulk density, glycemic response

Introduction

Bread is one of the fundamental food products, necessary in human nutrition. It is produced through baking dough made of flour, water and other additives. The dough is usually subjected to fermentation, either natural or with the help of leavening agents. Depending on the basic material used, bread is generally classified as wheat bread, rye bread, mixed grain bread, and others depending on the raw materials and the technology applied. Bread quality depends on the raw materials properties and technological process parameters (Rozylo and Laskoski, 2014).
Efforts have been made to promote the use of composite flours (Cotton seed and Sesame flour; Corn, Barley and Cassava; Breadnut flour, Pumpkin and Canola seed flour) in which flour from locally grown crops and high protein seeds replace a portion of wheat flour for use in bread, thereby decreasing the demand for imported wheat and producing protein-enriched bread (Olaoye et al., 2006) with reasonable level of fibre.
A diet high in fibre has many health benefits. The consumption of high fibre products may reduce the risk of cardiovascular disease, type 2 diabetes, obesity and some cancers and it can also improve digestive health (Duyff, 2012). High-fibre breads can make a particularly valuable contribution to a healthy diet, but growing scientific opinion suggests that the healthiest loaves of all are the ones with a low glycemic index (GI) - defined as giving the least exaggerated rise in blood sugar and the lowest insulin response.
Wheat, the basic ingredient in bread production is imported into Nigeria (Igbabul et al., 2014) involving huge expenditure of foreign exchange leading to high cost of the bread. In order to make bread affordable to larger population of consumers, there is the need to use novel source of crop such as quality protein maize. Quality protein maize (QPM) contains nearly twice as much usable protein as other maize (or corn) grown in the tropics and yields 10% more grain than traditional varieties of maize (Prassana et al., 2001; Palit and Suresh, 2003). It has been utilised in the production of several products like weaning food (Abiose and Ikujenlola, 2015), animal feed (Osei et al., 1999), biscuit (Giwa and Ikujenlola, 2010) information on its utilization as composite meal for producing whole meal bread is scanty. Therefore, with the initial claims on its protein quality, quality protein maize can be used as a substitute for wheat in bread.
This study was designed to assess the quality parameters of whole meal bread made from composite meals from whole grain of wheat and quality protein maize (QPM) with an aim to produce bread of high nutritional quality.

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Materials and methods

Materials

Wheat grains and QPM were obtained from new market, Obafemi Awolowo University and Obafemi Awolowo University Research farms, Ile-Ife, Nigeria respectively.

Methodology

Production of whole wheat and QPM flours

The grains were separately subjected to unit operations such as sorting, cleaning, and milling. The resulting meal was then packaged and kept until needed.

Formulation of blends

Wheat and QPM flours were blended at various ratios thus:
100% whole wheat flour:- 100%WWF
Composite flour 70% whole wheat flour and 30% whole QPM flour:- 70%WWF30%QPM
Composite flour 30% whole wheat flour and 70% whole QPM flour:- 30%WWF70%QPM
100% whole QPM flour:-100%QPM
Commercial whole wheat bread: - Control whole wheat bread

Bread making

Composite whole grain bread was produced using modified proportions of the samples as reported by Onuegbu et al. (2013) composite flour (57.00%), fat (2.00%), sugar (3.50%), yeast (1.00%), water (36.00%), salt (0.5%). All the ingredients were mixed in a Kenwood mixer for 10 minutes after which the resulting dough was kneaded. The dough was fermented in bowls and covered with wet clean muslin cloth for 55 minutes at temperature (35-36 ºC), punched, scaled to 250 g dough pieces and then placed in oiled pans for proofing. The dough was proofed in a proofing cabinet for 90 minutes at 32 ºC, 85% relative humidity and thereafter baked at 250 ºC for 30 minutes (Giami et al., 2004).

Proximate composition of various bread samples

Proximate composition (moisture, crude protein, crude fat, crude fibre, ash and carbohydrate by difference) of the bread samples was determined using the method of Association of Official Analytical Chemist (AOAC, 1990). The energy value of bread was calculated using the energy conversion factor:
$(4\ x\ 1g\ carbohydrate + 4\ x\ 1g\ protein + 9\ x\ 1g\ fat)$.

Sensory evaluation of the composite bread samples

Sensory evaluation of the composite bread samples was carried out by 10 semi-trained panellists drawn from Obafemi Awolowo University, Ile-Ife, Nigeria and questionnaire was presented to the panellists to record their observations. The panellists assessed the colour, aroma, taste, texture and overall acceptability using 7-point hedonic scale. A score of 1 represented "dislike very much" and a score of 7 represented "like very much" (Muhimbula et al., 2011).

Determination of physical properties of the bread samples

The loaf volume was measured by seed displacement method of AACC (2000). Loaf weight was determined by weighing using electronic balance; while the specific volume was obtained by dividing the loaf volume of the bread by its corresponding loaf weight.
Thus,

$$Specific\ volume = \frac{Volume\ (cm^3)}{Weight(g)} \qquad \text{(Eq. 1)}$$

The bread density was calculated as a ratio of loaf mass and volume (AACC, 2000).
The crust was separated from the crumb using the new razor blade. Crumb to crust ratio was expressed as weight ratio.
The dough expansion during fermentation was determined using a fixed amount (50 g) of dough placed in a graduated cylinder and fermented in an incubator (temperature 30 ºC, humidity 75%). The dough expansion over a fixed period (1 h) was then measured by recording the initial and final dough volume and expressed as percentage increase during the time of fermentation.

Functional properties determination of the flour samples

The functional properties were determined using standard methods water absorption capacity (Sathe and Salunkhe, 1981), swelling capacity and bulk density (Okezie and Bello, 1988) and pasting characteristics (Anonymous, 1990).

Glycemic response (glycemic index) determination

Glycemic response was determined by FAO (1998) method. Thirty volunteers (5 volunteers per sample) were requested to undergo an overnight fast of 10-12 hours. Fasting blood samples were collected by pricking the fingertip of the volunteers using the Softclix lancet device. The first drop of blood was placed onto the strip and a reading was taken (within 5-10 seconds) and recorded. White sliced bread containing 50 g available carbohydrate was used as the standard. Volunteers consumed the various bread samples containing 50 g available carbohydrate within 15 minutes and further blood samples were obtained at 30, 60 and 90 minutes intervals after taking the first bite. Total blood sugar level was determined from each of the blood samples with a portable glucometer. Blood glucose response chart was plotted from the average blood glucose concentration obtained pre and post-meal ingestion as a function of time after meal ingestion.

Statistical analysis

Data obtained from the experiment on proximate composition, functional parameters, dough expansion, sensory and physical parameters were expressed as mean ± SD. The analysis of variance (ANOVA) was performed to determine significant differences between the means. The means were separated using the Fisher's Least Significance Difference (LSD) test and Duncan multiple range test at $p<0.05$.

Results and discussion

Proximate composition of the bread samples

The proximate estimate of the various nutrients in the composite bread from wheat and QPM is presented in Table 1. The two grains are known to be low in protein this is confirmed from the results. The protein in wheat is reportedly lacking in two essential amino acids-lysine and tryptophan; these amino acids are reportedly present in reasonable amount in quality protein maize (Prassana et al., 2001; Abiose and Ikujenlola, 2014). The protein contents ranged between 9.98 and 10.25 %. There was no significant difference ($p>0.05$) between the protein of the bread samples. However, the substitution with QPM produced a better amino acids profile for the composite flours in view of the reported level of lysine and tryptophan in QPM (Abiose and Ikujenlola, 2014). QPM according to Prassana et al. (2001) and Abiose and Ikujenlola (2014) contain better amino acids profile in terms of lysine and tryptophan which are limiting in normal maize. White flour from wheat has been improved by supplementing with legumes like soy bean flour (Mashayekh et al., 2008).

The fat content obtained from the various samples ranged from 3.09% to 4.24%. The substitution of wheat with QPM reduced the fat level. There was significant difference ($p<0.05$) between the fat level of the bread samples. Fat plays a vital role in the determination of shelf life of foods. Foods high in fat have high energy value and encourage satiety; they also improve food flavour (Ihekeronye and Ngoddy, 1985; Byrd-Bredbenner et al., 2013).

The crude fibre content of the samples ranged from 2.39 to 2.84 %. The substitution with QPM increased the fibre content of the meal. According to Ihekoronye and Ngoddy (1985) wheat contains 2.00% crude fibre. Breads samples from whole grains have higher fibre content than refined flour. Food of high fibre is considered beneficial to human due to its ability to reduce the risk of certain medical conditions like obesity, type 2 diabetics and cardiovascular related diseases. However, very high intakes of fibre (i.e. above 50 to 60 g/day) can cause health risk. For example, high fibre consumption combined with low fluid intake can result in hard, dry stools that are painful to eliminate (Byrd-Bredbenner et al., 2013). The bread samples in this study can be grouped under medium fibre food. Their consumption could supply about 60% daily requirement of fibre for an average adult.

The moisture content of the composite flours increases with increasing QPM meal substitution. The highest moisture 10.20% was recorded for QPM flour. For better storage the meal should have reduced moisture content to prevent spoilage. High moisture content has been associated with short shelf life of composite breads as they encourage microbial proliferation that leads to spoilage (Ezeama, 2007).

The carbohydrate content of the flour samples ranged between 71.45 and 73.98 % indicating that the substitution with QPM does not have major effect on the carbohydrate content of the resulting samples. The carbohydrate content was lowest in 100% QPM. The carbohydrate content obtained for the composite bread samples were higher than those obtained from 10% soybean substituted QPM bread and 10% cassava substituted QPM bread (39.83% and 44.08% respectively) reported by Mesfin and Shimelis (2013). The composite samples contained energy values in the range of 353.53 to 369.40 kcal (Table 1). The energy values of the wheat, QPM and composite flours are function of protein, carbohydrate and fat of the flours. The bread samples including composite breads are reported to contain energy values in the range of 241 kcal to 266 kcal (FAO/WHO, 2001).

Table 1. Proximate composition of the various bread samples (%)

Parameters	100%WWF	70%WWF30%QPM	30%WWF70%QPM	100%QPM
Protein	$10.25^a \pm 2.34$	$10.08^a \pm 1.59$	$10.02^a \pm 2.40$	$9.98^a \pm 1.66$
Fat	$4.24^a \pm 0.44$	$3.14^b \pm 0.45$	$3.12^b \pm 0.66$	$3.09^b \pm 0.24$
Ash	$2.34^a \pm 0.24$	$2.42^a \pm 0.34$	$2.24^a \pm 0.66$	$2.44^a \pm 0.54$
Moisture Content	$8.22^c \pm 1.12$	$9.24^b \pm 0.88$	$8.20^c \pm 0.86$	$10.20^a \pm 1.10$
Carbohydrate	$72.56^a \pm 2.66$	$72.70^a \pm 3.20$	$73.98^a \pm 2.40$	$71.45^a \pm 2.00$
Crude Fibre	$2.39^b \pm 0.88$	$2.42^b \pm 0.22$	$2.44^b \pm 1.00$	$2.84^a \pm 1.22$
Energy Value (kcal)	$369.40^a \pm 2.60$	$359.38^b \pm 3.20$	$364.08^a \pm 2.40$	$353.53^b \pm 3.04$

*Data are mean values of triplicate determination ± standard deviation.

Sensory evaluation of the products

The assessment of the panellists showed that the whole meal breads were all acceptable (Table 2). However, there were significant differences ($p<0.05$) in some of the parameters assessed. The assessment showed that the colour of the whole wheat bread was the least acceptable while the commercial whole wheat bread which served as control was the most acceptable sample in terms of colour. The other samples were not significantly different ($p<0.05$) in terms of colour (Table 2).

The brownish appearance of the bread could be directly related to the increase in fiber content (Hu et al., 2007), caramelization and maillard reactions (Mohsen et al., 2009). The darker colour of the crumbs of whole wheat bread and fortified bread has been reported by other researchers (Akhtar et al., 2008; Serrem et al., 2011). Cereal bran influences the sensory properties of foods such as their colour, taste, mouth feel, and texture depending on its level of incorporation, bran particle size, and the treatment applied to the bran (Chinma et al., 2015).

The mean scores for taste of the composite bread samples were found to decrease with increased substitution with whole QPM meal. The 100%WWF had the highest mean score of 5.5 and 100 % QPM meal bread had the lowest mean score of 3.90. There was no significant difference ($p>0.05$) in the taste of the 100%WWF and control.

The control sample was ranked best for aroma and texture while the 100% QPM meal was rated least among the samples. The observations and scores of the panellists showed that there were significant difference ($p<0.05$) in aroma and texture of the bread samples. It has been reported that the baking conditions (temperature and time variables); the state of the bread components, such as fibres, starch, protein (gluten) whether damaged or undamaged and the amounts of absorbed water during dough mixing, all contribute to the final texture of the breads (Bakke and Vickers, 2007; Serrem et al., 2011).

The overall acceptability scores of the samples (Table 2) showed that the control was the most acceptable while the sample containing 100% QPM flour was the least acceptable to the panellists. The results of the panellist's assessment showed that substituting whole wheat bread with up to 70% whole QPM flour produced bread with acceptable quality.

Physical characteristics of various bread samples

In Table 3 are showed the values for selected physical properties of the bread samples. The bread volume (290.00-415.00 cm^3), bread specific volume (1.72-2.42 cm^3/g) and bread height ranged from 2.50 cm to 3.95 cm decreased as the level of substitution with whole QPM meal increased. Meanwhile, the bread length does not follow similar trend. The loaf volume and the bread height are good indicators of the crumb, how light and airy the interior of the breads are. Little values indicate a dense and compact crumb. Loaf weight reduction during baking is an undesirable economic quality to the bakers as consumers often get attracted to bread loaf with higher weight and volume believing that it has more substance for the same price (Shittu et al., 2007). These results agree with the reports of Rodriguez et al. (2006) and Islam et al. (2007) who reported that increased supplementation of wheat flour with defatted and non-defatted soy-flour reduced loaf height and specific volume drastically. The reports of Abboud and Brennan (2012) and Rubel et al. (2015) show that the main problem of dietary fibre addition in baking is the reduction of loaf volume and the different texture of the breads obtained. Studies show that loaf volume is affected by the quantity and quality of protein in the flour used for baking and also by proofing time, baking time and baking temperature (Shittu et al., 2007; Eriksson et al., 2014).

The bread density of the 100% QPM (0.59 g/cm^3) was the highest compared to other samples. There was increase in the bread density of composite bread as a result of the QPM addition. The crust to crumb ratio ranged between 0.25 and 0.36, with the bread from whole wheat meal having the highest value. The crust to crumb ratio of the samples declined with increasing substitution with whole QPM flour. This is due to the poor baking quality of QPM flour which hindered the complete formation of crust as compared with the samples containing wheat which has considerable amount of gluten. This also explains why 100% QPM had the lowest bread height, volume and crust to crumb ratio.

The crust colour is the degree of colour darkness in the crust ranging from pale to dark brown; the whole wheat bread had dark brown colour while the 100% QPM bread was lighter in colour.

Table 2. Sensory evaluation of bread samples

Properties	100%WWF	70%WWF30%QPM	30%WWF70%QPM	100%QPM	Control wheat bread
Colour	4.80_{b}	5.20_{ab}	5.90_{ab}	5.70_{ab}	6.10_{a}
Taste	5.40_{a}	4.40_{abc}	3.70_{bc}	3.00_{c}	4.90_{ab}
Texture	5.20_{a}	4.90_{a}	3.90_{a}	3.90_{a}	5.50_{a}
Aroma	5.10_{ab}	4.80_{ab}	4.40_{ab}	3.50_{ab}	5.50_{a}
Overall Acceptability	5.40_{a}	4.80_{ab}	4.00_{ab}	3.50_{b}	5.60_{a}

Any two means in the same row not followed by the same letter are significantly different at the 5% level.

Table 3. Physical parameters of the bread samples

Properties	100%WWF	70%WWF30%QPM	30%WWF70%QPM	100%QPM
Bread Height (cm)	$3.95^{a} \pm 0.07$	$3.45^{a} \pm 0.07$	$3.00^{b} \pm 0.28$	$2.50^{c} \pm 0.00$
Bread Length (cm)	$13.40^{a} \pm 0.00$	$13.60^{a} \pm 0.14$	$13.55^{a} \pm 0.07$	$13.35^{a} \pm 0.21$
Bread Volume (cm^3)	$415.00^{a} \pm 21.21$	$380.00^{b} \pm 13.50$	$315.00^{c} \pm 21.21$	$290.00^{d} \pm 14.14$
Bread Sp.Vol. (cm^3/g)	$2.42^{a} \pm 0.12$	$2.11^{b} \pm 0.10$	$1.80^{c} \pm 0.13$	$1.72^{c} \pm 0.09$
Bread Density (g/cm^3)	$0.42^{b} \pm 0.02$	$0.47^{b} \pm 0.00$	$0.56^{a} \pm 0.03$	$0.59^{a} \pm 0.04$
Crust : Crumb ratio	$0.36^{a} \pm 0.02$	$0.33^{a} \pm 0.01$	$0.25^{b} \pm 0.01$	$0.27^{b} \pm 0.01$

*Data are mean values of duplicate determination ± standard deviation.

Dough expansion of the flour samples

The dough expansion relates to the ability of the dough to rise as a result of fermentation which produces gas which is trapped within the network of the dough. The dough expansion of the various samples showed that the highest value (160%) was recorded for the 100% whole wheat meal, while 100% QPM had the lowest dough expansion (54.30%). The dough expansion declined with increasing substitution of whole wheat meal with QPM meal. This observation agrees with the reports Gomez et al. (2003) and Rubel et al. (2015) that addition of non-gluten flour during baking reduces loaf volume. Also the non-gluten (zein protein) in quality protein maize is responsible for the low dough expansion in QPM samples. This zein protein in QPM has no ability to trap the evolved gas during fermentation of dough this was responsible for the low dough expansion in QPM and QPM substituted samples.

Functional properties of the meal samples

The functional properties of composite meals are presented in Table 4. The water absorption capacities ranged from 22.50% to 45.00%. The inclusion of QPM meal resulted in the increase of the ability of the composite meal to absorb more water under experimental condition. Water absorption capacity (WAC) is the ability of a product to absorb and retain maximum amount of water under food formulation condition. The higher WAC of 100% QPM may be attributed to the proportion of hydrophilic amino acids in the protein and relative amount of carbohydrates. The more hydrophilic amino acids and the polysaccharide constituents, the more water the diet absorbs and binds (Otegbayo et al., 2006). The difference in water absorption is mainly caused by the greater number of hydroxyl group which exists in the fiber structure and allows more water interaction through hydrogen bonding (Nasser et al., 2008).

The bulk density of wheat meal (0.65 g/ml) was the lowest followed by that of the 100% QPM meal which recorded 0.68 g/ml. The 30%WWF70%QPM had the highest bulk density (0.73 g/ml). Usually, the lower the bulk density of a food powder, the higher the moisture content (Iheagwara, 2012). It was observed that the substitution of QPM in wheat meal resulted in increased bulk density of the composite meals.

The swelling capacities of the samples followed a similar trend with water absorption capacity ranging from 65.85% to 88.20%. Swelling capacity is the expansion accompanying spontaneous uptake of solvent. Swelling causes change in hydrodynamic properties of the food thus impacting characteristics such as body, thickening and increase viscosity of foods. The more hydrophilic amino acids and the polysaccharide constituents, the more water the diet absorbs and binds (Otegbayo et al., 2006).

Pasting characteristics of the meal samples

The pasting characteristics of the various samples are presented in Table 4. The highest final viscosity (256.17 RVU) was recorded for 100% QPM while 70%QPM30%WWF recorded the least final viscosity (231.42 RVU). The final viscosity of 256.17 RVU recorded for 100% QPM was lower than the final viscosities of 267.75 RVU and 458.08 RVU reported for QPM (Obatampa) and normal maize respectively by Abiose and Ikujenlola (2014).

Setback viscosity of starch-based foods has been correlated with texture of various food products. The high setback values of the composite bread samples indicate that the breads on baking will be cohesive. It has also been reported that low setback is an indication that the starch has a low tendency to retrograde or undergo syneresis during freeze thaw cycles (Otegbayo et al., 2006). The values obtained for the setback viscosity ranged from 87.08 to 124.08 RVU with 100%WWF recording the highest value and 30%WWF70%QPM recording the least value for setback viscosity. The pasting characteristics of the meals showed that substitution of QPM with wheat resulted in the decline of parameters like setback and final viscosity while the peak, trough and breakdown increased with the substitution.

The pasting temperature provides an indication of the minimum temperature required to cook a given sample and also indicates energy costs. The pasting temperatures of the meals were higher than the pasting temperature of 70.5 ºC reported for ‘Ogi’ (fermented corn) flour by Oluwamukomi et al. (2005), 66.7 ºC and 67.2 ºC for white and red sweet potato flours reported by Osundahunsi et al. (2003).

The peak time for pasting of the meal samples ranged from 4.66 to 5.66 minutes with 30%WWF70%QPM recording the highest and 70%WWF30%QPM recorded 5.19 minutes while 100%QPM recorded the least value for pasting time.

Glycemic response

The Glycemic Index (GI) is a measure of the extent of the change in blood glucose content (glycemic response) following consumption of digestible carbohydrate, relative to a standard such as glucose (Whelan et al., 2010). The mean blood glycemic responses of subjects fed with samples of composite bread and control are presented in Fig. 1. The blood glucose of all the 30 volunteers rose after taken the bread samples allotted to them. The peak rise for the composite bread occurred at 30 min and then declined while the rise was continuous for the control sample (white bread) over a 90 min period of investigation. Consumption of bread containing whole QPM flour resulted in decline glycemic response compared to the control; this may be attributed to the higher fibre content (>2.40%) of the composite breads compared to control (<0.50%). The control contains less than 0.50% crude fibre (Ali and Halim, 2013).

Pure QPM corn grits are observed to have a lower glycemic response compared to milled rice and the rice-corn grits mixture, which may be related in part to differences in their dietary fibre composition and physicochemical characteristics (Leonora et al., 2010). Pure QPM corn grits may be a more health beneficial food for diabetic and hyperlipidemic individuals. Low glycemic index foods produce low blood glucose and insulin response in normal subjects, and improve blood glucose control in Type 1 and well controlled patients with Type 2 diabetics (Wolever, 1992).

Glycemic index is a physiological classification widely accepted for carbohydrate foods, with implications on health and disease. The predicted percentage increase of prevalence of diabetes by year 2025 in the developed and developing countries will be 42% and 170% respectively (Hossain et al., 2007). The changes in life style that encourage reduced physical activity and consumption of diets high carbohydrate and excess calorie are the underlying factors responsible for this health issues. When considering the diet, intake of high GI foods are reported to be associated with development of insulin sensitivity, insulin resistance and increase in the risk of development of Type 2 diabetes and coronary heart disease (Gavin, 2001). The QPM substituted products gave low glycemic index possibly because of the fibre content. The products look promising to solving the problem of high glycemic index if reasonable quantity is consumed.

Table 4. Functional and pasting properties of meal samples

Properties	100%WWF	70%WWF30%QPM	30%WWF70%QPM	100%QPM
*Water Absorption Capacity(%)	22.50^{c} ± 7.07	25.00^{c} ± 3.00	30.00^{b} ± 2.20	45.00^{a} ±3.54
*Swelling Capacity(%)	65.80^{c} ± 3.68	83.35^{b} ± 4.74	86.67^{a} ± 0.10	88.20^{a} ± 0.10
*Bulk Density(g/ml)	0.65^{b} ± 0.02	0.71^{a} ± 0.01	0.73^{a} ± 0.01	0.68^{b} ± 0.01
**Peak 1 (RVU)	161.17	222.08	210.67	234.92
**Trough 1(RVU)	123.25	140.42	144.33	150.00
**Breakdown (RVU)	37.92	81.67	66.33	79.92
**Final viscosity (RVU)	247.33	233.00	231.42	256.17
**Setback (RVU)	124.08	92.58	87.08	101.17
Peak time (minute)	5.49	5.19	5.66	4.66
Pasting temperature (°C)	80.45	82.33	84.15	83.60

*Data are mean values of duplicate determination ± standard deviation.
**RVU = Rapid Visco Units (1RVU = 12 Centipoise)

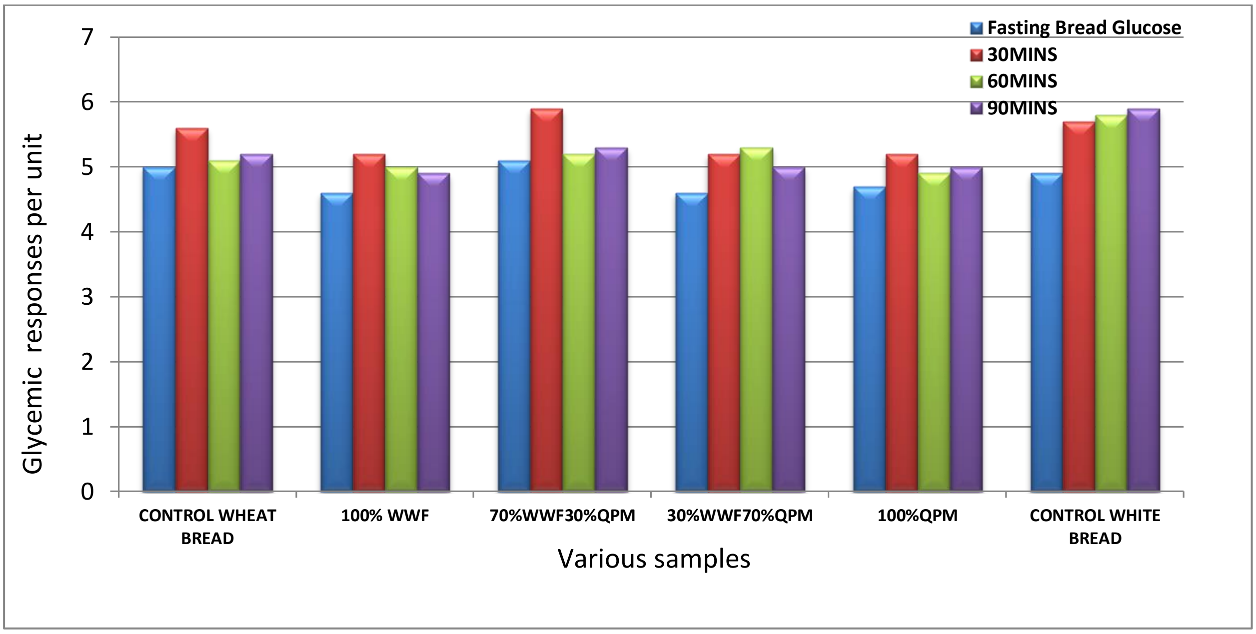

Fig. 1. Glycemic responses (glycemic index) of Bread samples

Conclusions

It could be concluded that good quality and acceptable whole grain bread could be produced from up to 70% substitution of wheat with quality protein maize. The QPM substituted breads contain higher crude fibre (2.42-2.84 %) compared to control sample (<2.00%) and recorded low glycemic responses of between 11.86-15.30 % reduction. The inclusion of QPM reduced the bread height (3.95-2.40 cm), volume (415.00-290.00 cm^3) and crust to crumb ratio (0.36-0.24). The QPM substituted breads were generally acceptable by the panellists in terms of colour, texture, and aroma. However, the whole wheat bread was rated higher than the QPM based whole grain bread in all the parameters assessed. This study also serves as an open window to further utilization of quality protein maize.

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