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Pasting properties of starch and protein in selected cereals and quality of their food products

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Abstract

In an attempt to improve intake of dietary fibre and antioxidants and quality of whole grain products, whole grain meals from barley, millet, rye and sorghum were evaluated individually and in blends with wheat flour in terms of starch pasting properties and protein heat damage, during cycles of heating and cooling in RVA tests. The whole grain meals were blended with either hard or soft wheat flour and processed into bread, cake, cookie or snack products. The products were then evaluated with regard to physical properties and acceptability. Significant differences were observed between cereals in starch peak, breakdown and setback viscosities as well as in protein peak viscosity. The results showed that RVA could be used to help formulate cereal blends with certain pasting properties. Substitution of wheat flour, with 15% of barley, rye, millet or sorghum whole grain, did not have significant detrimental effects on physical properties or acceptability of pita bread. Additionally, replacement of wheat flour with up to 30% of barley, rye, millet or sorghum whole grain meal had no significant effects on quality of cakes or cookies. A multigrain snack-like food was also developed as a healthy product and was highly acceptable in a sensory test. The developed product would help enhance consumption of whole grain foods, resulting in improved intake of fibre and health-enhancing components.

Keywords: Wheat; Barley; Millet; Rye; Sorghum; Flour; Wholemeal; Blends; RVA; Pasting properties; Pita bread; Cookie; Cake; Multigrain snack; Sensory properties

1. Introduction

At present, dietary guidelines recommend an increase in the consumption of whole grain cereal products due to their role in reducing the risk of degenerative chronic diseases. Several epidemiological studies have shown that consumption of whole grain cereals is associated with reduced incidences of diabetes (Liu et al., 2000; Pereira et al., 2002), cardiovascular diseases (Jacobs, Marquart, Slavin, & Kushi, 1998a, 1998b) and certain cancers (Jacobs, Marquart et al., 1998a, Jacobs, Meyer, Kushi, & Folsom, 1998b). In general, cereal products are recognized sources of dietary fibre and many bioactive components, such as lignans, phenolic acids, phytosterols, minerals, tocopherols and tocotrienols. These substances are mainly concentrated in the germ and outer layers of the kernel (Glitsø & Bach Knudsen, 1999; Hegedüs, Pedersen, & Eggum, 1985; Liukkonen et al., 1997). In order to maintain these substances in the end-products, whole grain flours and/or fortified flours are recommended for the production of health-enhancing or functional foods.

In many nations, including the developed countries, the consumption of whole grain products is far below the recommendations (Adams & Engström, 2000) with no exception for the Gulf region. In most of the Gulf

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countries, a diet rich in food of animal origin, fat and sugar is mainly being consumed (Al Kanhal, AL-Mohizea, AL-Qthaimeen, & Akmal Khan, 1999; Dashti, Al-Awadi, Sawaya, Al-Otaibi, & Al-Sayegh, 2003). Additionally, white Arabic flat bread, white toast bread and highly polished rice are the main staple foods in the Gulf region. Such food products provide a low dietary fibre intake, which results in higher incidences of constipation and related diseases, such as diverticulitis, appendicitis, piles, diabeties, and obesity among children, adults and elderly in the Gulf region (Eid & Bourisly, 1986; Hamadeh & Khalifa, 1998; Madani, Al-Amoudi, & Kumosani, 2000). In one study (Ragaee, Abdel-Aal, & Noaman, 2005), barley, pearl millet, rye and sorghum were adapted to grow in the United Arab Emirates (UAE) environment, and were found to contain reasonable levels of dietary fibre, minerals and antioxidants, showing good potential as functional food ingredients, i.e. to replace part of wheat flour in wheat-based food products.

Despite growing interest in the health aspects of whole grain products, good sensory properties still remain a key priority as a consumer choice criterion. Processing could have negative or positive effects on bioavailability of some nutrients (Clydesdale, 1994; Slavin, Jacobs, & Marquardt, 2000), but good organoleptic characteristics are a prerequisite for the consumption of whole grains. Processing must, first of all, provide products that have suitable form and good sensory properties. The objectives of the present study were to investigate pasting properties of starch and protein of barley, pearl millet, rye and sorghum whole grain meals, individually and in blends with wheat flour, the basic ingredient in making many staple foods, using a Rapid Visco Analyzer (RVA). This should help to better understand functionality of starch and protein during processing of whole grain products. The wholemeal/flour blends were processed into several common food products, including pita or flat bread, cake, cookie and snack foods. Quality and acceptability of the products were evaluated using objective and subjective methods.

2. Materials and methods

2.1. Materials

Three cereal crops, including barley (*Hordeum volgare* L.), pearl millet (*Pennisetum glaucum* L.) and sorghum (*Sorghum bicolor* L.), were grown at the Experimental Farm, College of Food Systems, UAE University. Rye was obtained from the Department of Plant Sciences, University of Saskatchewan, Canada. Bread and pastry wheat flours were kindly provided by the National Flour Mills CO. (L.L.C.), Jabel Ali, UAE. Barley and sorghum were dehulled on a Satake abrasive debranner mill model TM05 (Satake Corporation, Japan). The grains were ground using a Cyclone Sample Mill (UDY Corp., Fort Collins, CO) equipped with a 1.0 mm screen. The whole grain meal and wheat flour samples were kept in a refrigerator prior to analysis and processing.

2.2. Analytical methods

2.2.1. Pasting properties of starch

Pasting properties of starches in the whole grain meals and wheat flours and their blends were measured on a Rapid Visco Analyser (RVA-4), using the RVA General Pasting Method (Newport Scientific Pty. Ltd., Warriewood, Australia). A sample of 4.0 g of wholemeal or 3.5 g of wheat flour (14% moisture basis) was transferred into a canister and approximately 25 ± 0.1 ml distilled water were added (corrected to compensate for 14% moisture basis). The slurry was heated to 50 °C and stirred at 160 ppm for 10 s for thorough dispersion. The slurry was held at 50 °C for up to 1 min, and then heated to 95 °C over 7.3 min and held at 95 °C for 5 min, and finally cooled to 50 °C over 7.7 min. The pasting temperature (the temperature where viscosity first increases by at least 25 cp over a 20 s period), peak time (the time at which peak viscosity occurred), peak viscosity (the maximum hot paste viscosity), holding strength or trough viscosity (the trough at the minimum hot paste viscosity), final viscosity (the viscosity at the end of test after cooling to 50 °C and holding at this temperature), breakdown (peak viscosity – holding strength or trough viscosity) and setback (final viscosity – holding strength) were calculated from the pasting curve, using Thermocline version 2.2 software Newport Scientific Pty. Ltd. (Warriewood, Australia).

In a separate experiment, stirring number (SN, the viscosity at 3.0 min) was measured by the RVA, as described in the applications manual using the RVA Stirring Number Method. The SN is an indication of amylase activity and is highly correlated with falling number. The higher SN values indicate lower amylase activity.

2.2.2. Quality of protein by RVA

Properties of proteins in the whole grain meals and flours were measured by the RVA Flour Ethanol Method (Newport Scientific Pty. Ltd., Warriewood, Australia). The properties of the RVA second peak were used to determine properties of proteins during cycles of heating and cooling in aqueous ethanol. Second peak temperature, peak time, peak viscosity, final viscosity and breakdown (peak viscosity – final viscosity) were calculated using Thermocline version 2.2 software.

All RVA experiments were run in duplicate and the coefficient of variation of viscosity properties was less than 5% at any point along the curve.

2.3. Processing methods

2.3.1. Bread-making

Pita bread was made according to the method described by Abdel-Aal, Sosulski, Youssef, and Shehata (1993), in which 100 g (14% moisture basis) of wheat flour (control sample) or blended flour (wheat flour plus whole grain meal), 2.0 g active dry yeast, 1.5 g salt and water calculated according to water absorption of each flour or blend were mixed. The maximum replacement level for each whole grain meal in the blends (the level that had no dramatic effects on quality of pita bread) was determined using a set of preliminary baking experiments at several replacement levels, namely 0, 10, 15, 20% of each whole grain meal (results are not shown). The maximum acceptable replacement level (determined to be 15% w/w) was identified on the basis of bread characteristics (namely sensory properties, loaf diameter, loaf height, and layer separation). For each blend, three batches of dough were prepared and each batch was divided into four dough pieces prior to proofing and baking, giving a total of 12 loaves of pita bread per each cereal/wheat blend.

2.3.2. Cake- and cookie-making

Cakes and cookies were made according to the America Association of Cereal Chemists, Approved Methods, 10-90 & 10-52, respectively (AACC, 2003). A series of preliminary baking experiments at several replacement levels (0%, 10%, 20%, 30%, 40%) of each whole grain meal was carried out to determine the maximum replacement level which had no significant effect on the quality properties of each product (results are not shown). Based on the quality results, a 30% replacement level was found to produce acceptable products.

2.3.3. Snack food product

A new formula using a blend of barley, millet, rye and sorghum whole meals plus wheat flour was used to make a multigrain snack food product. The formula consisted of 100 g (14% moisture basis) of 10% of each cereal and 60% of wheat flour, 1.5 g active dry yeast, 1.0 g salt and water calculated according to water absorption of the blend. The ingredients were mixed for 3 min, followed by dough fermentation for 20 min at 30 °C and 85% relative humidity. The fermented doughs were cut into equally small balls (about 2 cm in diameter) and allowed to proof for 15 min at 32 °C and 90% relative humidity. The fermented balls were baked in a microwave oven or deep fried for few seconds and sprinkled with salt.

2.4. Volume of food products

Each baked product was allowed to cool to room temperature (left for about one hour after baking) prior to quality measurement. The volume of bread was measured by the rapeseed displacement method. The bread was placed in a container of known volume (total volume, V_t). The container was then topped up with rapeseed; after that, the bread was removed and the volume of rapeseed was recorded (V_s) (Abdel-Aal et al., 1993). Loaf volume was calculated as the difference between the total volume and volume of rapeseed, i.e. ($V_t - V_s$). Similarly, cake volume was measured. Specific volume was calculated from loaf volume and loaf weight or cake volume and cake weight. For cookies, diameter and height were measured.

2.5. Acceptability of end products by hedonic method

All product samples were coded and evaluated for degree of liking or disliking on a 9-point hedonic scale, using descriptive categories ranging from like extremely, through neither like nor dislike, to dislike extremely. The samples were presented randomly in identical containers and the panellists (15 staff) were asked to check the appropriate category on the scale. The descriptive categories were converted to numerical scores that were subjected to analysis of variance, as outlined in Watts, Ylimaki, Jeffery, and Elias (1989).

2.6. Statistical analysis

The data were subjected to analysis of variance and correlation analysis using Minitab software (version 12, Minitab inc., State College, PA) to determine differences in pasting properties and amylase activity among flour and whole grain samples.

3. Results and discussion

3.1. Pasting properties of starches

The RVA pasting properties of wheat flours, whole grain meals and their blends are presented in Table 1. The shape of the pasting curve differed depending on type of cereal flour and whole grain meal (Fig. 1). Significant differences were observed, among the cereal samples tested, in their behaviour during heating and cooling in excess of water. Among flours and whole grains, soft wheat flour samples had the highest peak viscosity (PV), trough viscosity (TV), and final viscosity (FV), while hard wheat flour exhibited much lower values of PV, TV and FV than did soft wheat flour. Pasting temperature and peak time were rather similar in the flours and whole grain meals, except for sorghum, which required a longer time (13.0 min) to reach maximum viscosity. This might be due to the lower rate of absorption and swelling of starch granules, as can be seen in Fig. 1. The PV of barley whole grain meal was comparable to that of hard wheat flour, millet

Table 1
Average RVA starch pasting properties of wheat flours, whole grain meals and their blends

Cereal grains	Pasting temp. (°C)	Peak time (min)	Peak viscosity (cp)	Trough viscosity (cp)	Final viscosity (cp)	Breakdown viscosity (cp)	Setback viscosity (cp)
Flours							
Hard wheat	94.9	9.1	1335	560	1402	775 (58)[a]	842 (60)[b]
Soft wheat	95.0	8.9	2599	1181	2531	1419 (55)	1351 (53)
Whole grains							
Barley	94.9	8.8	1355	366	1061	989 (72)	695 (66)
Millet	94.8	8.5	1130	656	2452	474 (42)	1796 (73)
Rye	95.0	8.6	1084	757	1770	328 (30)	1014 (57)
Sorghum	94.9	13.0	821	819	2126	2 (<1)	1307 (61)
Hard wheat blends (85% wheat flour + 15% l whole grain)							
+ Barley	86.0	9.0	1426	512	1404	915 (64)	892 (64)
+ Millet	86.9	9.1	1363	588	1826	775 (57)	1238 (68)
+ Rye	85.9	9.1	1596	658	1686	838 (53)	1028 (61)
+ Sorghum	86.6	9.0	1476	738	1941	738 (50)	1203 (62)
Soft wheat blends (85% wheat flour + 15% cereal whole grain)							
+ Barley	80.7	9.0	2073	732	1870	1341 (65)	1139 (61)
+ Millet	83.9	9.0	1956	808	2588	1148 (59)	1780 (69)
+ Rye	81.6	9.0	2370	1050	2370	1320 (56)	1347 (57)
+ Sorghum	83.5	9.0	2432	1237	2835	1195 (49)	1598 (56)

[a] Values in parentheses are percentage of breakdown.
[b] Values in parentheses are percentage of setback.

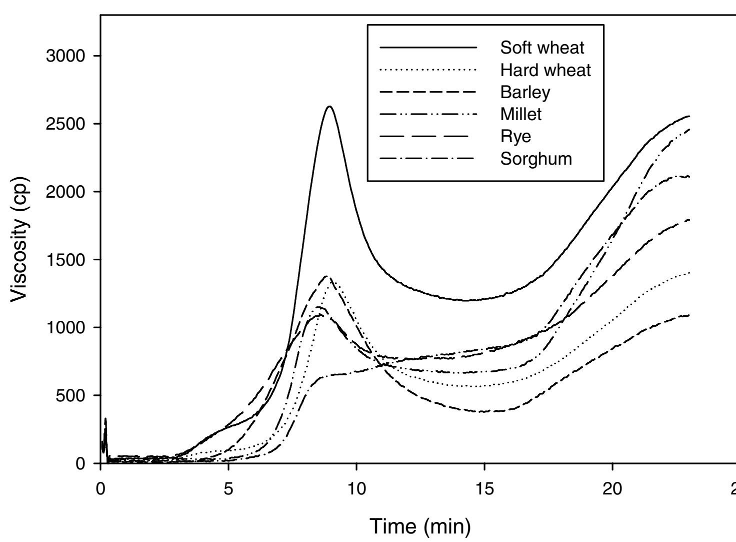

Fig. 1. RVA pasting curves of starches in wheat flours and cereal whole grain meals.

and rye slurries, showing intermediate degree of PV, whereas sorghum slurry exhibited a low PV. None of the whole grain cereals had a similar viscosity profile to hard or soft wheat flour. The results suggest that the cereal whole meal materials would behave differently during cooking and processing. The high content of starch in wheat flours compared to whole grain meals may contribute, to some extent, to the higher pasting viscosity. Additionally, differences in the protein composition in these cereals could also affect pasting viscosity and properties (Batey & Curtin, 2000; Morris, King, & Rubenthaler, 1997).

During the holding period of the viscosity test, the material slurries are subjected to high temperature and mechanical shear stress which further disrupt starch granules in the grains, resulting in amylose leaching out and alignment. This period is commonly associated with a breakdown in viscosity. The ability of starches to withstand heating at high temperature and shear stress is an important factor in many processes. High values of breakdown are associated with high peak viscosities, which in turn, are related to the degree of swelling of the starch granules during heating. More starch granules with a high swelling capacity result in a higher peak viscosity. This was the case in the soft wheat sample, which had a higher peak viscosity (2599 cp) and breakdown (1419 cp) than all other samples, followed by barley whole grain meal and hard wheat flour (peak viscosities were 355 and 1335 cp and breakdown viscosities were 989 and 775 cp, respectively). On the other hand, sorghum whole grain meal had the lowest peak viscosity (821cp) and breakdown (2 cp). The peak viscosity often correlates with quality of end-product and also provides an indication of the viscous load likely to be encountered by a mixing cooker. Unlike wheat flours, the whole grain meals examined were stable to heat and mechanical shear, except for barley.

During cooling, re-association between starch molecules, especially amylose, will result in the formation of a gel structure and, therefore, viscosity will increase to a final viscosity. This phase is commonly described as the setback region and is related to retrogradation and reordering of starch molecules. The low setback values indicate low rate of starch retrogradation and syneresis. There were significant differences in setback values between cereal flours and whole grain meals. When the setback was calculated as a percentage of final viscosity, soft wheat and rye had lower setback percentages, followed by hard wheat, sorghum and barley at intermediate setback, and finally millet at 73% setback.

The results of RVA starch pasting properties indicate that peak viscosities of barley, millet and rye whole grain meals are somewhat comparable to that of hard wheat flour with better paste stability, except for barley, and could be used to replace part of the wheat flour in several food formulas. Sorghum had the lowest peak viscosity but it showed the highest paste stability, as indicated by the lowest breakdown. This indicates that sorghum whole grain meal may have good potential as a food ingredient for food exposed to heat treatment at high temperature and mechanical stirring.

The starch pasting properties of cereal whole grain meals, in blend with wheat flour at 15% replacement level, showed significant effects on pasting behaviour of wheat flours (Table 1). For example, breakdown and setback viscosities, as a percentage of peak and final viscosity, respectively, became more consistent in the blends. Additionally, replacing part of the wheat flour with whole grain meals resulted in a decrease or increase in peak viscosity, depending on flour type (hard or soft), and also showed synergistic effects between starches in the blend. In general, pasting properties of wheat flour can be manipulated by replacing part of wheat flour with cereal whole grain meals. The replacement level and type of non-wheat cereal would be determined based on the desired pasting properties and end-uses.

3.2. Amylase activity

Stirring number of cereal flours and whole grain meals was determined as an indirect measurement of amylase activity. Significant variations in stirring number were observed between cereal grains (Fig. 2). Soft wheat flour had the highest stirring number (lowest amylase activity), followed by barley whole grain meal. Sorghum and millet had the highest amylase activity, as indicated by their lower stirring numbers. Hard wheat flour and barley whole grain meal were intermediate in amylase activity. The level of amylase activity in grains influences viscosity of starch, and thus pasting properties of their flours during processing. Several factors (such as pH, temperature, presence of minerals) can be used to control amylase activity and pasting properties of cereal flours and wholemeals.

3.3. Quality of proteins

Little information is available on using RVA for measuring quality of cereal proteins. RVA was used in

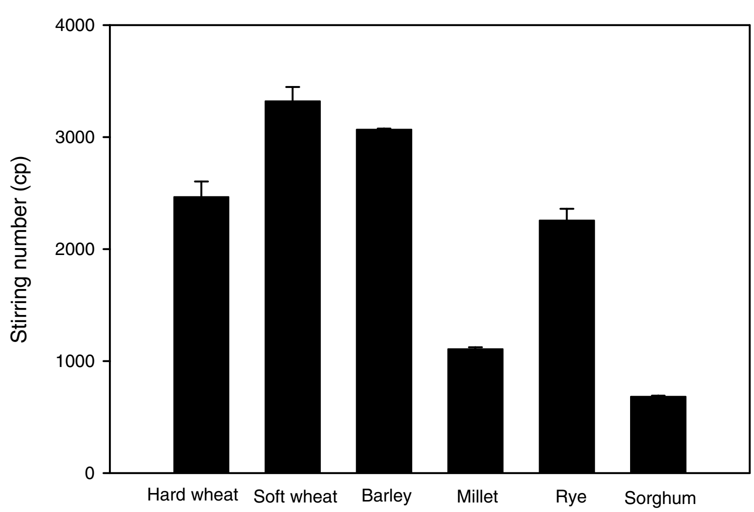

Fig. 2. Stirring number of wheat flours and cereal whole grain meals.

an attempt to determine quality of proteins in cereal grain flours and whole grain meals on the basis of protein damage when it is heated in aqueous ethanol. The viscosity of proteins subjected to heating and cooling cycles were measured as a function of time, temperature and mechanical shear. The second peak of the RVA curve was used to determine protein properties, including peak time (PT), peak temperature (PTm), peak viscosity (PV), final viscosity (FV) and breakdown. Significant differences in these parameters were observed between wheat flours (hard versus soft) and among cereal whole grain meals (Table 2). Additionally, the shape of the second peak was unique for each cereal (Fig. 3). Hard wheat flour significantly differed from soft wheat flour in PTm, PV, FV and breakdown, indicating significant variations in protein properties when subjected to heating and cooling treatments. Significant differences were also observed among cereal whole grain meals in PT, PTm, PV, FV and breakdown, showing different responses of proteins in these cereals. These results suggest that RVA can differentiate between cereal flours and/or whole grain meals in terms of protein quality and characteristics.

Wheat flours and barley whole grain meal slurries had higher second peak viscosities than did other flour and whole grain samples. The peak viscosity was observed during the cooling cycle at somewhat similar times (peak time 19–20 min). This may be explained

Table 2
Average RVA protein heat damage properties of wheat flours, whole grain meals and their blends

Cereal grains	Peak temp. (°C)	Peak time (min)	Peak viscosity (cp)	Final viscosity (cp)	Breakdown viscosity (cp)
Flours					
Hard wheat	40.7	19.0	1766	246	1520
Soft wheat	30.0	21.5	2578	822	1756
Whole grains					
Barley	66.8	19.8	2117	1249	868
Millet	49.0	17.1	1004	108	896
Rye	34.1	21.0	1558	675	883
Sorghum	44.0	18.2	387	129	258
Hard wheat blends (85% wheat flour + 15% whole grain)					
+ Barley	42.1	19.0	1975	595	1380
+ Millet	48.5	17.0	2064	324	1740
+ Rye	43.0	18.5	2009	443	1566
+ Sorghum	46.0	19.5	1889	344	1545
Soft wheat blends (85% wheat flour + 15% whole grain)					
+ Barley	39.1	20.0	2415	620	1795
+ Millet	48.0	18.0	2669	411	2258
+ Rye	38.5	20.0	2490	669	1821
+ Sorghum	42.9	19.0	2468	379	2089

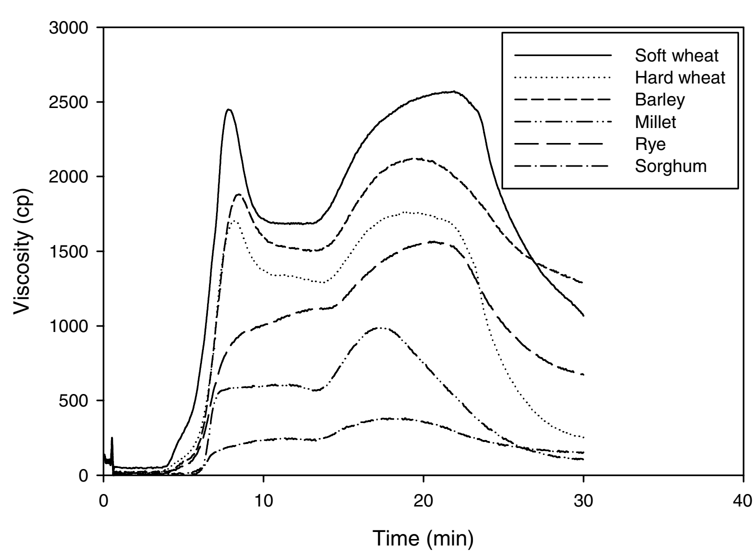

Fig. 3. RVA heat damage curves of proteins in wheat flours and cereal whole grain meals.

by similar storage proteins in wheat and barley, namely, prolamines or alcohol-soluble proteins. Rye, which belongs to the same tribe as wheat and barley, also had a relatively higher second peak viscosity than had millet or sorghum. Still, there were substantial differences between millet and sorghum in the second peak viscosity. Significant differences were also observed in the final and breakdown viscosities among cereal whole grain meals. It seems that RVA can be used to characterize proteins in non-wheat cereal grains. This requires further investigation to better understand RVA data in relation to quality of these grains. Little or no information is reported on using RVA to study protein quality of non-wheat cereal grains. Protein quality of wheat flour/cereal wholemeal blends was different from wheat flours, the base material in the blends. In the case of hard wheat blends, the viscosity of proteins changed due to replacing part (15%) of the flour with cereal whole grain meals. For soft wheat blends, addition of barley and rye resulted in reduction in PTm, while addition of millet and sorghum increased PTm. Peak times were almost similar in soft wheat blends and flours, while peak and final viscosities were reduced compared to soft flour alone, except for peak viscosity of millet blend. It seems that replacing part of wheat flour with cereal whole grain meal not only changes pasting properties of starch, but also the protein composition of the blends.

In general, the RVA results indicate that cereal flours and whole grain meals have a wide range of pasting properties, and RVA could be used to help formulate cereal blends with certain pasting properties. When starch and protein peak viscosities of individual flours, whole grain meals and blends (12 samples) were subjected to statistical analysis, a significant correlation ($r = 0.8342$) was found between the two peak viscosities (Fig. 4). This correlation may indicate degree of starch gelatinization, level of protein denaturation and their interaction. This phenomenon warrants further investigation using a large number of cereal grains to better understand interaction of protein and starch during heating and cooling cycles.

3.4. Physical properties and acceptance of end products

Incorporation of 15% of barley, millet, rye or sorghum whole grain meal into a baking formula of pita bread had very little effect on bread specific volume or loaf height as compared with the control bread sample (100% wheat flour) (Fig. 5). The blends produced breads that were characterized by good-looking appearance, two-layers or pocket-type bread and were comparable to the control bread, except for having a darker colour, particularly in the case of millet and sorghum breads. Colour of bread varied, depending upon the type of non-wheat cereal incorporated in the blend. The wheat/sorghum blend produced breads having the darkest crust, perhaps due to high concentration of the red pigments in the outer layers of the grains. The crusts of the breads made from wheat/millet and wheat/rye blends were slightly darker than the control breads, while the crust of the bread baked from wheat/barley blend was almost similar to the control sample. The coarsest texture was obtained with the bread made from wheat/millet blend, while the other breads had a firmness that was similar to the control sample. The sensory test showed that substitution of wheat flour with 15% of barley, rye, millet or sorghum whole grain meal did not have significant adverse effects on overall acceptability of pita bread (Fig. 8). The overall acceptability was categorized as "like very much" for barley and rye and "like moderately" for millet and sorghum. Similar

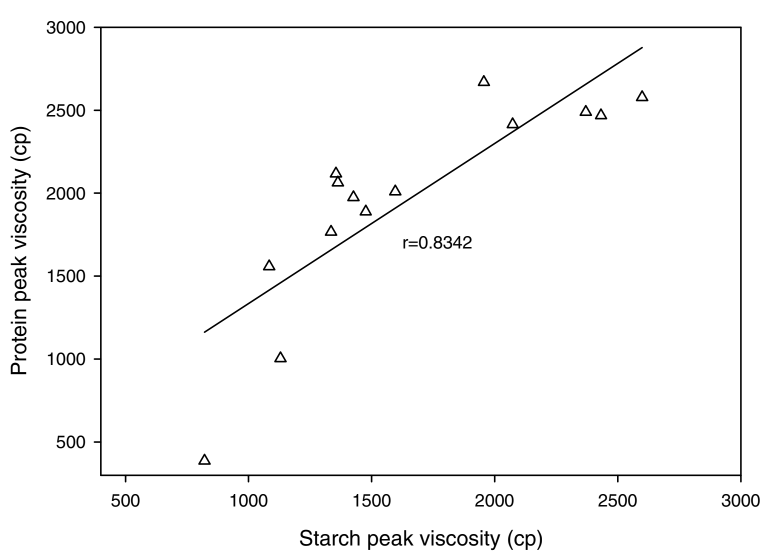

Fig. 4. Relationship between starch peak viscosity and protein peak viscosity of wheat flours, cereal whole grains and blends.

sensory results for wheat/sorghum and wheat/millet breads were obtained by Munck (1994) and Dendy (1992) and for wheat/rye bread by Heinio, Liukkonen, Katina, Myllymaki, and Poutanen (2003) Ragaee, Campbell, Scoles, McLeod, and Tyler (2001).

Substitution of wheat flour with 30% of barley, rye, millet or sorghum whole grain meal had no significant effects on the quality (i.e. cookie height and diameter) of cookie products (Fig. 6). The height and diameter of cookies were almost similar in whole grain and control samples. The acceptability test of cookies showed no significant differences between cereal whole grain-containing cookies and 100% wheat flour cookies (Fig. 8).

In the case of cakes, specific volume of control samples was slightly higher than those of whole grain-containing cakes (Fig. 7). Additionally, the sensory test showed no significant differences between control and non-wheat-containing cakes (Fig. 8). In our previous study, the whole grain meals were found to have higher levels of dietary fibre, minerals and antioxidants than had wheat flours (Ragaee et al., 2005). This would help improve nutritional quality of such baked products, resulting in higher dietary intake of fibre and health-enhancing components.

A blend of barley, millet, sorghum and rye whole grain meal plus wheat flour and food additives was formulated and processed into a healthy snack product. The acceptability of the developed cereal-based snack-like food product was assessed by measuring degree of liking on a hedonic scale (Fig. 8). The snack food product was categorized as ''like very much'', based on overall acceptability. Studies on the nutritional quality and nutrient bioavailability in the developed multigrain snack product are underway.

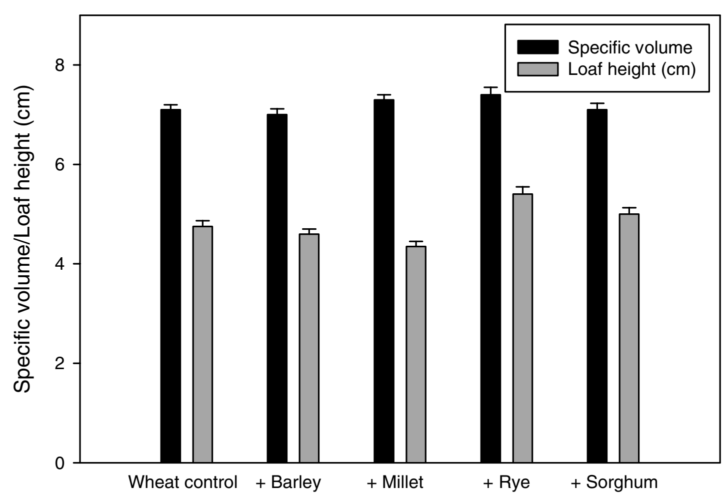

Fig. 5. Specific volume and loaf height of pita breads baked from control flour and cereal whole grain blends.

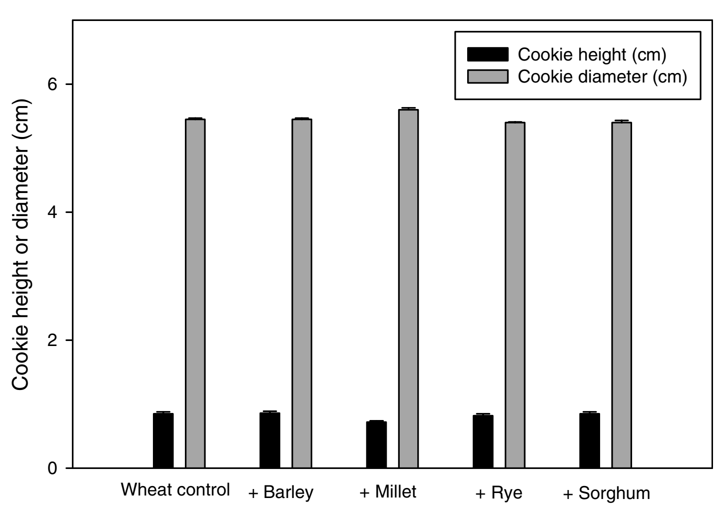

Fig. 6. Height and diameter of cookies made from control flour and cereal whole grain blends.

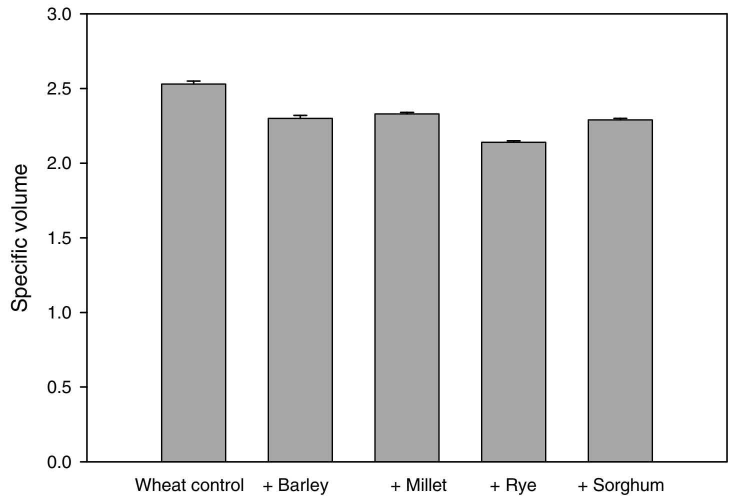

Fig. 7. Specific volume of cakes made from control flour and cereal whole grain blends.

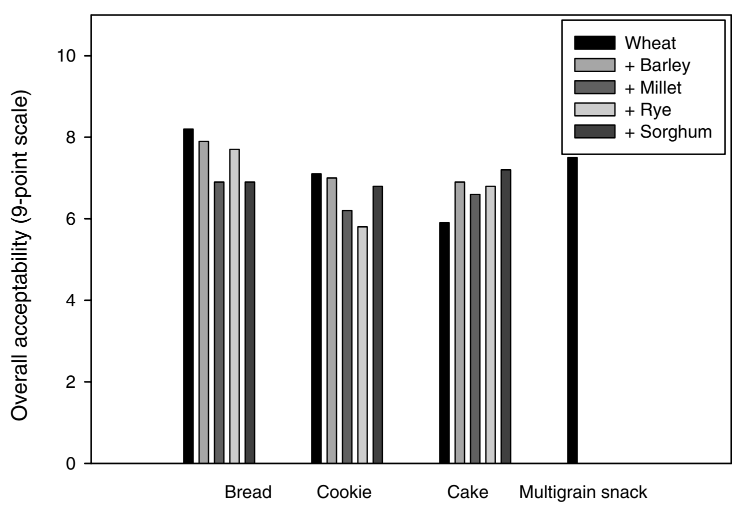

Fig. 8. Overall acceptability of pita bread, cookie, cake and snack food products made from control flour and cereal whole grain blends on a 9-point hedonic scale by a sensory test.

4. Conclusions

The high contents of dietary fibre and antioxidants in whole grain products provide a fundamental basis for incorporation of such grains into foods as health-enhancing ingredients. Surprisingly, the whole grain-containing bakery products (pita bread, cake and cookie) were comparable with the control products (100% wheat flour) in terms of physical properties and acceptability. This could encourage consumption of whole-grain containing food products, resulting in promotion of good health of individuals in countries where mainly bakery products made from 100% wheat flour are consumed. Additionally, the RVA studies showed that multigrain blends could be manipulated to provide a certain range of pasting properties for specific end-use. Further research on using RVA to study interaction of protein and starch during heating and cooling cycles is needed.

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