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# Antioxidant activity and nutrient composition of selected cereals for food use

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**Abstract**

Whole grain products are recommended for healthy diets as being recognized sources of dietary fiber and antioxidant substances. In the present study, four cereals including barley, pearl millet, rye and sorghum which are adapted to the growing conditions in the United Arab Emirates were evaluated in terms of their composition of dietary fiber, resistant starch, minerals and total phenols and antioxidant properties. Antioxidant activity was evaluated on the basis of scavenging capacity of 2,2-diphenyl-1-picrylhydrazyl ($DPPH^{\cdot}$) radicals and 2,2′-azino-di-[3-ethylbenzthiazoline sulphonate] ($ABTS^{\cdot+}$ radical cations). The adapted grains exhibited better nutritional quality compared to commercial hard and soft wheat flours, the main ingredients in grain-based food products. They were significantly rich in resistant starch, soluble and insoluble dietary fibers, minerals and antioxidants. Barley had the highest levels of phosphorus, calcium, potassium, magnesium, sodium, copper, and zinc, and the second highest content of iron following millet. Sorghum was exceptionally high in antioxidant activities followed by millet and barley. The antioxidant properties of the three grains were comparable to butylated hydroxytoluene. The nutritional data suggest that the selected grains, particularly barley and sorghum, hold promise as healthy food ingredients.


*Keywords:* Wheat; Barley; Millet; Rye; Sorghum; Flour; Whole grain; Protein; Resistant starch; Dietary fiber; Minerals; Total phenols; Antioxidant activity; DPPH test; ABTS test

## 1. Introduction

Several reports have shown that sorghum (Duodu, Taylor, Belton, & Hamaker, 2003) and millet (Pathak, Srivastava, & Grover, 2000) are inexpensive and nutritionally comparable or even superior to major cereals. Grain sorghum and millet are also important food cereals in many parts of Africa, Asia and the semi-arid tropics world wide. In Africa, India and China, grain sorghum comes third among cereals for human consumption, superseded only by rice and wheat (El khalifa & El Tinay, 2002). In Northern and Eastern Europe, rye is a traditional cereal that is generally used as whole meal flour in both soft and crisp breads (Nilsson et al., 1997). Barley grains also have been investigated for several potential new applications as a whole grain or for its value-added products. There are a variety of food applications of barley in India, China and the West Asia–North Africa region (WANA) (Bhatty, 1999).

The above cereal crops (barley, millet, rye and sorghum) can also grow and give higher and more stable grain yields in regions characterized by low rainfall or drought, high temperature and low soil fertility. In other words, they perform well under poor soil and growing conditions. The environment and climate in the United Arab Emirates (UAE) are characterized

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by such conditions, and thus adaption of these cereals to the UAE is of great interest. In the development and introduction of these crops to the UAE, there is a need to evaluate their nutritional quality and potential uses (Ragaee & Abdel-Aal, 2004). Nevertheless, little information is available on the production and quality of these grains in the UAE.

Recent studies (Juntunen et al., 2000; Karppinen, Myllymaki, Forssell, & Poutanen, 2003; Rieckhoff, Trautwein, Malkki, & Erbersdobler, 1999) have shown that cereal grains contain constituents that have demonstrated health benefits for humans, such as antioxidants and anti-disease factors. For instance, phytic acid was found to play a major role in the treatment of cancer, hypercholesterolemia, hypercalcuria and kidney stones (Plaami, 1997). Other studies have also demonstrated that diets high in carbohydrate, rich in dietary fiber, and largely of cereal origin, allowed withdrawal of oral hypoglycaemic agents or a reduction of insulin dose in diabetic subjects (Pathak et al., 2000). Additionally, several health claims on grain dietary components have been approved by the FDA in the USA.

Keeping in mind the necessity for increasing dietary fiber and other bioactive dietary components in the diet, additional plant food sources are needed. Whole grain products have the potential to make a good contribution in this respect as recognized sources of dietary fiber, minerals, vitamins, and antioxidants. The present study was carried out to evaluate nutritional quality, particularly with respect to minerals and fiber components, of selected new adapted cereals for the food industry in the Gulf region. Total phenols and antioxidant properties of the whole grains were also evaluated and compared with wheat flours.

## 2. Materials and methods

### 2.1. Grain 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 (*Secale cereale* L.) was obtained from the Department of Plant Sciences, University of Saskatchewan, Canada. Rye was included in the study because it is currently being evaluated for adaptation under the growing conditions in the UAE. A composite sample of about 10 kg from each grain representing different locations was used in the present study. Wheat (*Triticum aestivum* L.) flours milled from hard and soft grains were kindly provided by the National Flour Mills Co. (L.L.C.), Jabel Ali, UAE. Barley and sorghum grains were dehulled using 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 until analysis.

### 2.2. Analytical methods

#### 2.2.1. Chemical composition

Whole grain meals and commercial wheat flours were analysed for moisture, ash and fat according to the Approved Method of the American Association of Cereal Chemists, Method 44–16, Method 08–01, Method 30–10, respectively (AACC, 2003). Starch was measured as glucose on a Yellow Springs Instrument (YSI) model 2700 (Yellow Springs Instrument Co., Yellow Springs, CO), following hydrolysis with α-amylase and amyloglucosidase using a Megazyme assay kit (Megazyme Int. Ireland Ltd., Wicklow, Ireland). The YSI uses immobilized glucose oxidase for the determination of glucose in starch hydrolysates. Protein was determined based on the combustion method using a nitrogen analyzer (FP 2000 Leco Instrument UK Ltd., Stockport, Cheshire, UK). The sample ($30 \pm 2$ mg) was combusted at 1150 °C in a sealed furnace. Measurements were validated by analyzing four standard compounds, Atropina (4.84% N), DL-metionina (9.39% N), acetanilide (10.36% N) and nicotinamide (22.94% N) and by running blank and standard samples prior to the actual sample analysis. The protein content was expressed as nitrogen multiplied by a factor depending on the type of cereal (5.7 for wheat flour, 5.83 for rye and barley whole grains, and 6.25 for millet and sorghum whole grains).

#### 2.2.2. Dietary fiber and resistant starch

Total, insoluble and soluble dietary fiber contents were quantified using the enzymatic gravimetric procedure of the AACC Method 32–07 (AACC, 2003). Arabinogalactan from Sigma was used as a standard reference for the determination of total dietary fiber, giving accuracy of 95.3%. Resistant starch (RS) was determined using the Megazyme assay kit (Megazyme Int. Ireland Ltd., Wicklow, Ireland). This method is based on removal of non-resistant starch by hydrolysis with α-amylase and amyloglucosidase for 16 h at 37 °C. The RS is then recovered as a pellet by centrifugation, washed with ethanol and dissolved in potassium hydroxide solution, and was quantitatively hydrolyzed to glucose with amyloglucosidase. The accuracy of the determination of RS was checked with standard materials of corn flakes (2.27% RS) and Kidney bean (4.58% RS). The relative accuracy values were 97–98%.

#### 2.2.3. Minerals

Samples were prepared for the determination of minerals as described by Heckman (1971). The minerals

were determined by using Inductively Coupled Plasma Atomic Emission Spectrometry, ICP-AES Varian-Vista-MPX, (Varian, Inc.) as outlined in the manufacturer's manual.

#### 2.2.4. Extraction of samples

Extracts for the determination of total phenols and antioxidant activity were prepared by weighing 5 g flours or ground grains and mixed with 50 ml of 80% methanol. The mixture was purged with stream of nitrogen and thoroughly mixed on IKA shaker for 30 min, then centrifuged at 6000 rpm for 20 min. The extracts were transferred into culture tubes, purged with a stream of nitrogen and then kept in a refrigerator until analysis.

#### 2.2.5. Total phenols

Total phenols content was based on the Folin-Ciocalteu method of Kaluza, McGrath, Roberts, and Schroder (1980) using gallic acid as a standard. The reaction mixture contained 250 μl of grain extract, 250 μl of diluted Folin-Ciocalteu reagent and 500 μl of saturated sodium carbonate solution. The mixture was brought up to 5 ml with distilled water, and the contents were mixed and kept in darkness for 30 min. The mixture was centrifuged at 6000 rpm for 10 min, and the absorbance was read at 725 nm. The total phenols content was calculated as gallic acid equivalent using the average molar absorptivity of gallic acid. The molar absorptivity of gallic acid was calculated by Beer's law using a series of gallic acid concentrations measured under the test conditions. The molar absorptivity of gallic acid ranged from 16,845 to 18,259 $m^{-1}$/cm with an average of 17,559 $m^{-1}$/cm standard deviation of 583 $m^{-1}$/cm and relative standard deviation of 3.3%.

#### 2.2.6. Radical DPPH scavenging capacity

The free radical scavenging capacity of grain extracts was determined using the stable 2,2-diphenyl-1-picrylhydrazyl radical (DPPH·) as outlined by Yu, Perret, Harris, Wilson, and Haley (2003). The antioxidant reaction was initiated by transferring 1 ml of grain extracts into a test tube containing 4 ml of 80% methanol and 1 ml (containing 1 mmole) of freshly prepared DPPH· solution. The final concentration of DPPH· in the reaction mixture was 167 μmole. The reaction was monitored by reading absorbance at 517 nm for 30 min at 2 min intervals. A blank reagent was used to study stability of DPPH· over the test time. The absorbance measured at 10 min was used for the calculation of μmoles DPPH· scavenged by grain extracts. The kinetics of the antioxidant reaction in the presence of grain extracts were also determined over a 30 min period and compared with butylated hydroxytoluene (BHT) as an antioxidant reference.

#### 2.2.7. Radical cation ABTS scavenging capacity

The radical cation (2,2′-azino-di-[3-ethylbenzthiazoline sulphonate]) ($ABTS^{\cdot+}$) scavenging capacity was measured using a Randox Laboratories assay kit (San Francisco, CA). Trolox (6-hydroxy 2,5,7,8-tetramethylchroman-2-carboxylic acid) provided in the kit was used as an antioxidant standard and for the calculation of scavenging capacity of grain extracts as trolox equivalent. The scavenging activity of grain extracts was calculated as μmole ABTS/g sample at different times (3, 5, 6 and 9 min) for valid comparison between samples.

### 2.3. Statistical analysis

All analyses were carried out in triplicate and the data were reported as means ± standard deviation. The data were subjected to correlation analysis to identify relationships between samples using Minitab software (version 12, Minitab inc., State College, PA).

## 3. Results and discussion

### 3.1. Nutrient composition

The major nutrient composition (starch, protein, ash and fat) of wheat flours and cereal whole grain meals are presented in Table 1. It was obvious that refined flours, hard wheat flour (bread flour) and soft wheat flour (pastry flour) had the highest starch content averaging approximately 77.7% due to the removal of the fibrous outer kernel layers during the milling process. Among whole grain cereals, barley and rye contained relatively lower starch contents (53.6% and 58.0%, respectively), compared to millet and sorghum which had starch content of about 67.5%. Starch, the main source of energy in plant foods, is further categorized into rapidly digested starch, slowly digested starch and resistant starch on the basis of digestibility. These nutritional starch fractions are different in cereal grains depending upon species, preparation of flours and processing conditions.

Table 1
Chemical composition (% dry basis) of wheat flours and whole grain cereals

| Cereal | Starch | Protein ($N\times$ factor)[a] | Total ash | Crude fat |
|---|---|---|---|---|
| Hard wheat | 77.4 ± 1.7 | 13.5 ± 0.3 | 0.56 ± 0.01 | 0.98 ± 0.03 |
| Soft wheat | 77.9 ± 1.8 | 11.0 ± 0.2 | 0.71 ± 0.01 | 0.86 ± 0.03 |
| Barley | 53.6 ± 1.0 | 19.4 ± 0.4 | 2.88 ± 0.04 | 2.31 ± 0.1 |
| Millet | 67.4 ± 1.3 | 8.8 ± 0.1 | 1.82 ± 0.03 | 4.22 ± 0.2 |
| Rye | 58.0 ± 1.0 | 13.3 ± 0.2 | 1.96 ± 0.03 | 2.53 ± 0.1 |
| Sorghum | 67.7 ± 1.2 | 12.1 ± 0.1 | 1.87 ± 0.03 | 3.32 ± 0.1 |

[a] Nitrogen-to-protein conversion factors are: 5.7 for wheat flour, 5.83 for rye and barley whole grain, and 6.25 for millet and sorghum whole grain.

Resistant starch in the grains will be discussed later in the dietary fiber section.

Protein content varied substantially among whole grain meals and wheat flours (Table 1). Barley whole grain had the highest protein content, approximately 19.4%, while rye and hard wheat flour contained intermediate levels, averaging 13.4%. Millet whole grain exhibited the lowest level of protein (8.8%), while soft wheat flour had 11.0% and sorghum 12.1%. Pomeranz (1981) stated that high nitrogen fertilization, in most instances, increases storage proteins and thus total protein of barley. In general, the storage proteins in cereal grains commonly lack some of the amino acids that are considered essential for the human diet especially lysine and other dietary sources for lysine need to be added to cereal containing diets.

As expected whole grain cereal meals contained higher content of total ash or minerals compared to refined wheat flours (Table 1). Again, barley whole grain had the highest total ash content (2.9%) among cereals, followed by rye, millet and sorghum (1.8–1.9%).

Crude fat ranged from 0.9% in soft wheat flour to 4.2% in millet whole grain meal (Table 1). The high content of fat in whole grain products is due to the presence of embryo in which oil is concentrated. Barley and rye whole garins contained relatively lower fat compared to sorghum and millet. The high content of fat in millet (4.2%) should be taken into consideration during storage and processing. Hoseney, Varriano-Marston, and Dendy (1981) found that the quality of millet flour deteriorates during storage as it turns bitter due to the high fat content, high unsaturated fatty acids and high enzymatic hydrolytic activities. Additionally, oxidative degradation of lipids results in high hexanal production (Kaced, Hoseney, & Varriano-Marston, 1984).

In pearl millet, lipids are divided into free lipids (petroleum ether extractable, ranging from 5.6% to 7.1%) and bound lipids (extractable with water-saturated butanol, ranging from 0.6% to 0.9%) (Lai & Varriano-Marston, 1980). The unsaturated fatty acids average 70.3% of the free lipids. Triacylglycerols are the major components of millet lipids, the rest being sterol, esters, hydrocarbons and free fatty acids (Cupta, 1980). Approximately 84% of the fatty acyls are unsaturated in millet oil (Dhindsa, Dhillon, & Sood, 1982). In sorghum there is 2.0–4.1% free lipids and 0.1–0.56% bound lipids, the major portion of the lipids is found in the germ (Pomeranz, 1981). Sorghum lipids are highly unsaturated, with oleic and linoleic acids accounting for at least 76% of the total fatty acids (Pomeranz, 1981). The greatest portion of lipids in barley is triacylglycerols (73.3–79.1%) which are primarily composed of palmitic, oleic, linoliec and linolenic acids (Price & Parsons, 1975). Several publications on nutrient composition in sorghum and wheat (Lovis, 2003), rye, millet and barley (Gabrovska et al., 2002), millet (Malik, Singh, & Dahiya, 2002) and rye (Ragaee, Campbell, Scoles, McLeod, & Tyler, 2001) are in agreement with the present study.

### 3.2. Composition of dietary fiber

The fiber composition of wheat flours and cereal whole grains are presented in Table 2. Resistant starch (RS) represents the part of starch escaping digestion and not absorbed in the small intestine of healthy humans. It is considered as dietary fiber and several reports have shown that cereal and legume food products high in RS and slowly available glucose contents are characterized by reduced glycemic index (Englyst, Vinoy, Englyst, & Lang, 2003; Tharanathan & Mahadevamma, 2003; Wisker, 2000). Millet and sorghum were higher in RS compared to wheat flours and the other cereal whole grains. RS was 2.0% and 1.8% in millet and sorghum, respectively, while it was <1.0% in the remainder of cereal whole grains and flours.

Soluble dietary fiber ranged between 1.4% in sorghum whole grain and 3.7% in rye whole grain. Rye and barley whole grains contained the highest level and can be considered as good sources of soluble dietary fiber. Insoluble dietary fiber content markedly varied among cereal whole grains and flours ranging from 13.5% to 22.1% in whole grains and from 1.9% to 3.0% in wheat flours. Barley and sorghum were significantly high in insoluble dietary fiber (22.1% and 19.6%, respectively). Millet and rye contained reasonable levels of insoluble dietary fiber (13.5% and 14.1%, respectively). Total dietary fiber (including resistant starch) was in the following order: barley (24.6%), sorghum (21.0%), rye (17.8%) and millet (15.0%). Malleshi, Hadimani, Chinnaswamy, and Klopfenstein (1996) reported lower values of total dietary fiber in millet and sorghum (11% and 8%, respectively), which could be

Table 2
Dietary fibers composition (% dry basis) of wheat flours and whole grain cereals

| Cereal | Soluble dietary fiber | Resistant starch | Insoluble dietary fiber | Total dietary fiber |
|---|---|---|---|---|
| Hard wheat | 1.61 ± 0.01 | 0.20 ± 0.02 | 2.98 ± 0.01 | 4.59 ± 0.21 |
| Soft wheat | 1.78 ± 0.01 | 0.55 ± 0.01 | 1.87 ± 0.01 | 3.65 ± 0.11 |
| Barley | 2.56 ± 0.03 | 0.23 ± 0.01 | 22.07 ± 0.41 | 24.63 ± 0.52 |
| Millet | 1.45 ± 0.01 | 1.96 ± 0.01 | 13.50 ± 0.32 | 14.95 ± 0.41 |
| Rye | 3.70 ± 0.02 | 0.20 ± 0.01 | 14.07 ± 0.23 | 17.77 ± 0.53 |
| Sorghum | 1.42 ± 0.01 | 1.77 ± 0.02 | 19.59 ± 0.41 | 21.01 ± 0.41 |

due to different genotypes. Wheat flours had a relatively very low content of total dietary fiber due to removal of bran or the outer kernel layers. Several studies (Gabrovska et al., 2002; Lovis, 2003; Malik et al., 2002; Ragaee et al., 2001) showed that whole grains contain higher concentration of dietary fiber compared to wheat flours and would enhance dietary fiber intake. Joanne, David, and Marquart (2001) compared chemical composition of wheat flours at different extraction rates (from 66% to 100%). Their results indicate that as the extraction rate increased, all nutrients increased except for starch which decreased with increasing the extraction rate. Ragaee et al. (2001) reported higher values of dietary fiber in different rye and triticale flours compared to wheat flour at the same extraction rate. The results obtained justify using whole grain cereals in bakery products as sources of dietary fiber.

The dietary fiber components in sorghum are mainly cellulose and pentosan. Cellulose level was reported to be 1.19–5.23% (Kamath & Belavady, 1980). The pentosan content of sorghum whole grain ranged from 2.51% to 5.57% depending on variety and environment (Karim & Rooney, 1972). The main dietary fiber fraction in rye is arabinoxylan and it was reported that rye grains contain 9.1% arabinoxylan, 2.3% cellulose, 1.8% β-glucan and 1.2% Klason lignin (Aman, Nilsson, & Andersson, 1997). In barley, β-glucan is the major component of dietary fiber at level of about 22% of the total dietary fiber, followed by pentosan (19.7%), Klason lignin (7.8%) and resistant starch (6.3%) (Bhatty, 1999).

### 3.3. Minerals composition

In general, whole grains contained higher levels of minerals compared to wheat flours due to the presence of the outer kernel layers where minerals are concentrated (Table 3). Among the whole meal products, barley had the highest levels of phosphorus, calcium, potassium, magnesium, sodium, copper and zinc, and it was the second highest in iron content (128.4 mg/kg) after millet. Rye appears to be rich in iron (43.0 mg/kg) and manganese (24.4 mg/kg), while millet had the highest content of iron (199.8 mg/kg), cobalt (0.27 mg/kg) and chromium (7.7 mg/kg), and the second highest calcium content (508.6 mg/kg). Sorghum had the lowest concentration of all minerals, exhibiting a poor mineral profile compared to barley and rye.

### 3.4. Total phenols and antioxidant properties

Several studies have shown that 80% methanol is an effective solvent in extracting phenolics and other polar substances in cereals (Przybylski, Lee, & Eskin, 1998; Zielinski & Kozlowska, 2000). In this study, 80% methanol extracts from cereals were used for the determination of total phenols content and antioxidant properties. Whole grains and wheat flours significantly differed in total phenols content ranging from 501 to 562 μg/g in wheat flours and from 879 to 4128 μg/g in whole grains (Table 4). Sorghum had the highest total phenols content, while barley possessed the lowest content. Millet and rye were intermediate in total phenols compared with sorghum. The total phenols content in barley and oat whole grains was found to be higher than that of wheat and rye and lower than that of buckwheat (Zielinski & Kozlowska, 2000).

Antioxidant properties of whole grains and wheat flours were evaluated on the basis of measuring scavenging activity for DPPH radicals and ABTS radical cations by grain methanolic extracts. In the DPPH test, the coloured stable DPPH radical is reduced in the presence of an antioxidant or a hydrogen donor into non-radical DPPH-H, and the reduction in colour is monitored over time. The colour intensity of DPPH radicals with no antioxidants or grain extracts was stable over the test time with an average absorbance of 1.739 (Fig. 1). This average absorbance was used for the calculation of DPPH scavenging capacity. The antioxidant extracts from whole grains and wheat flours were found to exhibit different reaction kinetics curves compared with the BHT antioxidant standard (75 ppm). The grain extracts showed a sharp drop in DPPH colour intensity, indicating high antioxidant activity in quenching DPPH radicals during the first few minutes followed by a logarithmic decay. In the presence of BHT, however,

Table 3
Mineral composition (mg/kg) of wheat flours and whole cereal grains

| Mineral | Hard wheat | Soft wheat | Barley | Millet | Rye | Sorghum |
|---|---|---|---|---|---|---|
| P | 3498 | 977.6 | 4570 | 2879 | 3620 | 349.9 |
| K | 826.2 | 1225 | 4572 | 2798 | 3570 | 239.9 |
| Mg | 301.2 | 306.5 | 1971 | 1488 | 1328 | 187.7 |
| Ca | 159.5 | 202.2 | 736.2 | 508.6 | 348.7 | 27.3 |
| Na | 46.0 | 38.4 | 238.4 | 60.89 | 67.2 | 4.6 |
| Zn | 30.8 | 7.6 | 74.2 | 65.9 | 30.6 | 3.1 |
| Fe | 13.2 | 13.9 | 128.4 | 199.8 | 44.0 | 10.6 |
| Mn | 5.2 | 8.1 | 9.2 | 8.1 | 24.4 | 1.2 |
| Cu | 1.4 | 1.6 | 5.7 | 3.4 | 2.9 | 0.2 |
| Cr | 0.1 | 0.001 | 0.9 | 7.7 | 0.7 | 0.8 |

Relative standard deviation of minerals ranged from 1.5% to 4.9%.

Table 4
Total phenols content and antioxidant properties of wheat flours and whole grain cereals

| Cereal | Total phenols as gallic acid equivalent (μg/g) | DPPH scavenging capacity at 10 min (μmole/g) | ABTS scavenging capacity at 3 min (μmole/g) |
|---|---|---|---|
| Hard wheat | 562 ± 28.8 | 4.33 ± 0.17 | 8.8 ± 0.39 |
| Soft wheat | 501 ± 25.5 | 4.17 ± 0.17 | 8.3 ± 0.31 |
| Barley | 879 ± 24.0 | 21.00 ± 0.83 | 14.9 ± 0.61 |
| Millet | 1387 ± 13.3 | 23.83 ± 0.67 | 21.4 ± 0.43 |
| Rye | 1026 ± 16.9 | 12.17 ± 0.50 | 13.0 ± 0.48 |
| Sorghum | 4128 ± 9.3 | 195.8 ± 8.82 | 51.7 ± 0.57 |

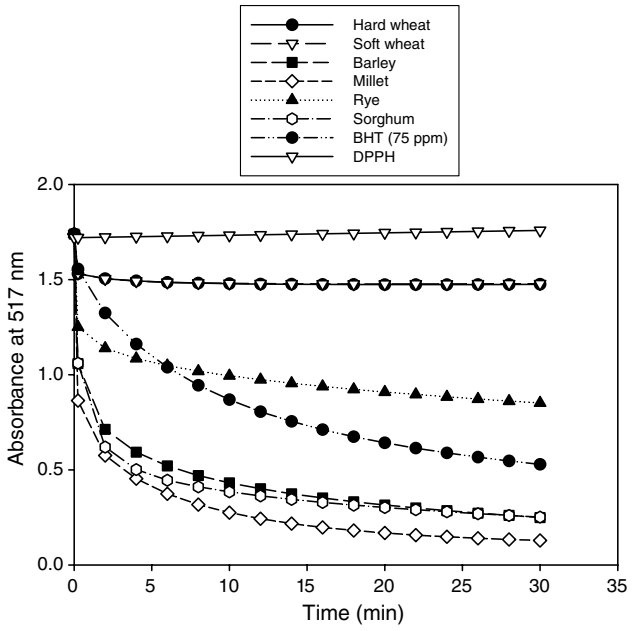


Fig. 1. Kinetics of DPPH radical with wheat flour extracts, cereal whole grain extracts and BHT.

the colour intensity of DPPH· gradually reduced over time following a logarithmic decline. Hard and soft wheat flours were identical in their reaction kinetics having slight effects in quenching DPPH· only during the first minute. Sorghum (diluted ten-folds), millet and barley extracts had similar reaction kinetics, exhibiting strong antioxidant activity in scavenging DPPH radicals. Rye extract had relatively an intermediate reaction rate compared to other whole grain extracts. The results suggest different kinetics and mode of action for grain extracts compared to BHT.

The DPPH scavenging activity after 10 min reaction was similar for hard and soft wheat flour averaging approximately 4.3 μmole/g sample (Table 4). Sorghum was exceptionally high in quenching DPPH· at 195.8 μmole/g compared with 23.8 and 21.0 μmole/g for millet and barley, respectively. Rye had the lowest DPPH scavenging capacity (12.2 μmole/g) among whole grain products.

The ABTS test is based on the formation of $ABTS^{\cdot+}$ by reacting ABTS with metmyoglobin and $H_2O_2$ at 37 °C. The $ABTS^{\cdot+}$ has a relatively stable blue-green colour which is measured at 600 nm. In the presence of an antioxidant such as 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (trolox) or potential antioxidants in material extracts, the colour production will be suppressed to a certain extent in proportional to the concentration of antioxidants. The ABTS scavenging activity of wheat flour and whole grain products at different reaction times is presented in Fig. 2. Sorghum whole grain had the highest capacity in quenching $ABTS^{\cdot+}$ at the four reaction times followed by millet and barley. Rye whole grain and wheat flours showed relatively low $ABTS^{\cdot+}$ scavenging activities at the examined four times. Data in Table 3 showed $ABTS^{\cdot+}$ scavenging capacity after 3 min reaction for wheat flours and whole grains. The $ABTS^{\cdot+}$ scavenging activity of several cereal methanolic extracts was in the following order: buckwheat > barley > wheat cv. Henika > oat > rye ≡ wheat cv. Almari (Zielinski & Kozlowska, 2000). The antioxidant activity in grains was influenced by genetic and environmental factors (Yu et al., 2003; Yu, Haley, Perret, & Harris, 2002).

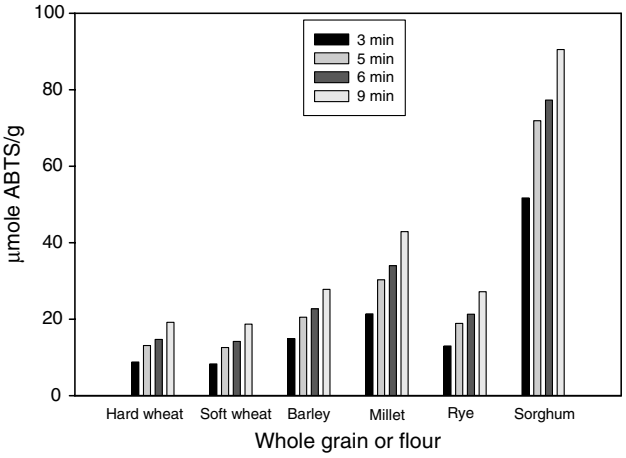


Fig. 2. Radical cation ABTS scavenging capacity of wheat flour and cereal whole grain extracts at different time.

Significant correlations were observed between total phenols content and DPPH scavenging activity ($r = 0.988$) and ABTS scavenging activity ($r = 0.996$) indicating the role of phenolic compounds in inhibiting free radicals and radical cations under these systems. The results suggest that phenolic compounds in grains may be able to fight free radicals formed in the human body. A significant correlation was also found between DPPH scavenging activity and ABTS scavenging activity ($r = 0.981$). Similarly, strong correlations ($r = 0.80$–$0.99$) were observed between total phenols and methanolic extracts from whole grain and grain fractions of buckwheat, barley, oat, wheat and rye (Zielinski & Kozlowska, 2000).

## 4. Conclusions

The role of whole grain products in nutrition and health has been scientifically documented. Whole grains are recognized sources of several physiologically active components and/or health promoters. It has also been well known that bioactive substances occur in grains at different concentrations and identities depending upon genotypes and phenotypes. Sorghum, millet and barley adapted to the UAE environment were found to contain reasonable levels of dietary fiber and antioxidant properties. Incorporation of such materials into bakery products would enhance their nutritional and physiological

properties, but their functionality and acceptability should be taken into consideration.

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