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Antioxidant properties of wheat mill streams

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Knowing the quality of mill streams is very important for getting flours with improved quality. In the present work, 49 mill streams, obtained by milling common wheat with an industrial roller mill, were characterized in terms of phenolic content, antioxidant activity and iron content. The antioxidant activity was estimated using different methods: DPPH-radical scavenging, Trolox equivalent antioxidant capacity, and iron reducing antioxidant power. The break tailings and first tailings of the reduction passages had the largest contents of iron. The total phenolic contents (TPC) from flour streams ranged between 76.3 and 369 mg ferulic acid equivalent/100 g d.w. The highest TPC were obtained for the second fractions resulting from 1st and 2nd break rolls. The highest antioxidant activity was registered for flour streams collected from: the last two break rolls, the reduction rolls that process the tailings of the first three reduction passages and bran finisher. Trolox equivalent antioxidant capacity had the same trend as DPPH-radical scavenging activity. The highest iron reducing antioxidant power was found in the tailings of the reduction rolls. The knowledge provided by this study could be successfully applied for getting flour with improved antioxidant activity and iron content by mixing different types of mill streams.

1. Introduction

Wheat kernels consist of endosperm, pericarp, seed coat, and germ. The endosperm is composed of the starchy endosperm and aleurone layer. The starchy endosperm comprises starch and proteins. The aleurone layer is rich in proteins, minerals and vitamins, and usually breaks away with the outer layers (pericarp and seed coat) in the milling process. The outer layers form the bran and are rich in non-starch polysaccharides (arabinoxylans, cellulose and beta-glucans). The bran and the germ are relatively rich in proteins, fats, B vitamins and minerals (Dewettinck et al., 2008).

Wheat milling is a mechanical gradual reduction process when the endosperm is separated from the bran layers. The quality of the mill streams resulting from different technological passages depends on the wheat selected for milling and on the flow sheet followed in the mill (Prabhasankar et al., 2000). The composition of the mill streams varies due to the heterogeneous distribution of chemical components in the kernel. This challenging issue was intensively studied and many reports on mill streams characterization exist in the literature. Rani et al. (2001) studied the distribution of alpha-amylase, protease, lipoxygenase, polyphenol oxidase and peroxidase in wheat roller flour mill streams. Dornez et al. (2006) investigated the distribution of arabinoxylans, endoxylanases, and endoxylanase inhibitors over the wheat mill streams and their correlation with ash, starch, and protein contents, as well as the alpha-amylase activity levels. The distribution of ash, starch, proteins (Every et al., 2002; Prabhasankar et al., 2000) and arabinoxylans (Wang et al., 2006) over different wheat roller mill streams was investigated quite extensively. The total plant sterols, steryl ferulate, steryl glycoside, tocopherols and tocotrienols contents in grains milling fractions were studied by Engelsen and Hansen (2009).

Many recent studies focused on determining the antioxidant capacity of the native or processed whole cereals and pseudocereals. Orozco et al. (2010) investigated the influence of the wheat genotype on the phenolic acid content, while Dordevic et al. (2010) analyzed the total phenolics and antioxidant activities of native and fermented plant materials (wheat, rye, barley, buckwheat). In addition, different milling fractions from durum and/or breadwheat (Beta et al., 2005; Esposito et al., 2005; Liyana-Pathirana and Shahidi, 2007; Sedej

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Abbreviations: ABTS, 2,2-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt; BF, bran finisher; B1/B2–B5, breaks; C1–C9, reductions; CMD, coarse middlings divider; DPPH, 1,1-diphenyl-2-picrylhydrazyl; DPPH RSA, DPPH-radical scavenging activity; FRAP, iron reducing antioxidant power; TEAC, trolox equivalent antioxidant capacity; TPC, total phenolic contents; TPTZ, 2,4,6-tri-2-pyridyl-s-triazine; Trolox, 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid.

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et al., 2011; Zhokhov et al., 2010; Zhou and Yu, 2004), and waxy wheat (Hung et al., 2009) were investigated in terms of antioxidant activity. Due to the differences in terms of extraction methods and data interpretation applied by different authors, it is generally difficult to compare the results from the literature. Zielinski and Kozlowska (2000) established the following hierarchy of total phenol contents (extraction in 80% methanol, v/v) extracted from different whole grains: buckwheat > barley > oat > wheat = rye. On the other hand, Dordevic et al. (2010) reported in their studies (extraction in 70% ethanol, v/v) the following hierarchy based on total phenol contents: buckwheat > barley = wheat > rye.

The appropriate selection of the mill streams for obtaining different end-use products highly depends on the knowledge on their composition and functionality. Some mill streams, mainly those originating from the outer layers of the kernel, are not commercially available but are included in different flour blends.

The aim of the present study was to investigate the antioxidant properties and iron content of the mill streams in order to gather information for obtaining flour mixtures formulations with high antioxidant properties. We analyzed the mill streams (tailings and sifted), flour and bran, to trace the origin of the fractions collected at the end of milling process of common wheat.

2. Materials and methods

2.1. Materials

Romanian common wheat, Glosa cultivar (harvested in 2010 from Eastern Romania), was milled to an extraction rate of 77%, with an industrial roller mill (Buhler, Uzwil, Switzerland, roller mill Newtronic MDDO&MDDM, plansifter MPAJ, impact machine MJZE) having a capacity of 3300 kg/h. The wheat was tempered prior to milling up to the final moisture of 15%. The tempering process was done using an automatic system (Buhler, Uzwil, Switzerland) consisting of two units, the moisture controller unit MYFC and the water metring system MOZF, coupled with a dampener MOZL. The wheat tempering was achieved as follows: 66% of the total water was used in the first step when the moisture content of 14.5% was achieved after 6–8 h; in the second tempering step the moisture content of 15% was achieved after 3–4 h; eventually the wheat was water-spayed for about 30 min to prevent the weight loss due to evaporation.

The industrial roller mill consisted of four break rolls, nine reduction rolls (C1–C9), one coarse middlings divider, three bran finishers, and one turbostar sifter. The characteristics of the roller mill and the milling diagram ensure an efficient particle size separation that compensates the absence of the purifier machines. From the wheat milling process, 49 mill streams resulted: 3 break flour fractions (B1/B2, B3, B4), 10 reduction flour fractions (C1I, C1II, C1III, C2/C3I, C2/C3II, C2/C3III, C4I, C4II, C5I, C6), 1 flour fraction from coarse middlings divider (CMD), 1 flour fraction from bran finisher (BFII), 1 break feed flour fraction (B5), 6 reduction feed flour fractions (C5II, C7I, C7II, C8, C9I, C9II), 2 bran fractions (C9/R1, BFI) and 25 tailings. The origin and destination of the mill streams that enter and exit every mill, and the mesh of the sieve are indicated in Table 1.

Table 1
The origin and destination of the mill streams that enter and exit every mill, and the mesh of the sieve.

Origin	Destination	Mesh of the sieve (μm)	Type of fraction: tailing (R)/sieve (S)
B1/B2	B3	>1000	R1
	C1	1000–400	R2
	C2/C3	400–280	R3
	CMD	280–140	R4
	Flour fraction F(B1/B2)	<140	S1
B3	BF	>1250	R1
	B4	1250–530	R2
	C4	530–250	R3
	C5	250–140	S2
	Flour fraction F(B3)	<140	S1
B4	BF	>1120	R1
	B5	1120–335	R2
	C7	335–125	R3
	Flour fraction F(B4)	<125	S1
B5	BF	>400	R1
	C9	400–300	R2
	C8	300–112	R3
	Feed flour fraction F(B5)	<112	S1
CMD	C2/C3	>125	R1
	Flour fraction F(CMD)	<125	S1
C1	C4	>450	S1
	C2/C3	450–200	S2
	Flour fraction F1(C1)	<140	S1
	Flour fraction F2(C1)	<160	S2
	Flour fraction F3(C1)	<200	S3
C2/C3	C4	>315	R1
	C5	315–180	R2
	Flour fraction F1(C2/C3)	<140	S1
	Flour fraction F2(C2/C3)	<160	S2
	Flour fraction F3(C2/C3)	<180	S3
C4	C5	>1120	R1
	B4	1120–315	R2
	Flour fraction F1(C4)	<140	S1
	Flour fraction F2(C4)	315–140	S2
C5	C6	>125	R1
	Flour fraction F1(C5)	<125	S1
	Feed flour fraction F2(C5)	<125	S2
C6	C7	>125	R1
	Flour fraction F(C6)	<125	S1
C7	B5	>280	R1
	Feed flour fraction F1(C7)	<125	S1
	Feed flour fraction F2(C7)	280–125	S2
C8	C9	>125	R1
	Feed flour fraction F(C8)	<125	S1
C9	Bran fraction	>160	R1
	Feed flour fraction F1(C9)	<112	S1
	Feed flour fraction F2(C9)	<160	S2
BF	Bran fraction	>200	R1
	Flour fraction (BF)	<200	S1

Samples of mill streams (200 g) were collected on three different days to ensure that differences caused by the milling procedure were taken into account. The samples collection for the quantitative–qualitative balance was made in keeping with the succession of the passages according to the milling diagram. The collected samples were ground in a laboratory mill to diminish the particle size to pass a 125 mesh sieve and then stored in plastic bags at 4–5 °C until testing. The fractions sampling was according to the standard SR EN ISO 13690:2007 (ASRO, 2008).

The reagents 1,1-diphenyl-2-picrylhydrazyl (DPPH), 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (Trolox), 2,2-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS) and ferulic acid were purchased from Sigma–Aldrich Chemie GmbH (Taufkirchen, Germany), Folin–Ciocalteu reagent was purchased from Merck & Co., Inc. (New York, USA), while 2,4,6-tri-2-pyridyl-s-triazine (TPTZ) and all other chemicals and solvents having the highest commercial grades available were purchased from Fluka Chemie GmbH (Buchs, Switzerland).