

## **IMPACT OF MULTIGRAIN MILLING ON THE CHEMICAL PROFILE OF THE MILL STREAMS**

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**Abstract:** The multigrain blends prepared by mixing wheat + rye + hulled oat, wheat + rye + hulled barley and wheat + rye + triticale in three different ratios of 80:10:10, 70:15:15 and 60:20:20 were milled with an experimental roller mill. The resulted mill streams (six flour streams, one bran stream and one short stream) were analysed in terms of chemical composition, total phenol contents and antioxidant activity. The fractions collected from the reduction passages had higher protein contents than the fractions resulted from break passages. All flour fractions from multigrain milling had lower protein contents than wheat flour fractions. Higher total phenol contents and antioxidant activity were obtained for mill streams resulted through multigrain milling compared to the mill streams resulted from wheat milling. The highest antioxidant activity was registered for fractions resulted from multigrain milling of blends with 20 % hulled barley, triticale and hulled oat.

**Keywords:** *antioxidant properties, chemical composition, flour streams, multigrain milling, roller mill*

## INTRODUCTION

Through the roller milling process the cereal are subjected to successive grinding and sieving in order to separate the endosperm as flour and the outer layer and germ as bran. Regardless of the complexity of mill flow diagram, different mill streams are generated from every technological passage. The yield, physical-chemical and functional properties vary with the mill stream, because of the differences in terms of composition of different anatomical parts of the grain. The outer layer is rich in arabinoxylans, cellulose and  $\beta$ -glucans, germ is rich in fats, proteins and vitamins, the aleurone layers have high contents of proteins, minerals and vitamins, while the starchy endosperm is rich in starch and protein [1]. Therefore, depending on the participation of these anatomical parts of the grain on mill streams, their composition will vary. Moreover, by combining the mill streams different types of flours with different end uses can be obtained. When increasing the extraction rate, higher amounts of aleurone layer end up into flour, which become richer in many important nutrients, affecting on the other hand the bread making quality [1].

The mill streams resulted through milling wheat, rye, triticale, oat and barley with roller mill have different compositions. Regarding roller milling the rye, Gomez et al. [2] reported gradual increase of protein, ash,  $\beta$ -glucans and damaged starch content of the mill streams as the process advanced. Dewettinck et al. [1] reported that for the same yields of rye and wheat flours, the total and soluble fiber are higher in rye flour than in wheat flour. The increase of the yields resulted in higher total fiber for both cereals. The flour yield obtained when milling triticale with roller mill is generally low, but can be increased by conducting the tempering process at low moisture [3]. The same conditions favour the increase the protein content of triticale flour. According to Doehlert and Moore [4], the bran and coarse flour streams resulted through milling the oat with an experimental roller mill have higher contents of protein, fat, ash and  $\beta$ -glucans than the fine flour streams. The starch,  $\beta$ -glucans, ash and protein contents of mill streams depend by de type of experimental roller mill and the flow diagram [5, 6]. Lower contents of the above mentioned nutrients were found in the fine flour streams.

In this work the multigrain blends based on wheat, rye, triticale, hulled oat and hulled barley were milled with an experimental roller mill. The resulted mill streams were characterized in terms of chemical composition, total phenol contents and antioxidant activity.

## MATERIALS AND METHODS

### Materials

The following cereals were used in the experiments: wheat (Boema variety), rye (Suceveana variety) and triticale (Oda FD variety), harvested in 2016 in South Eastern Romanian Plain, while hulled barley and hulled oat purchased from a specialized market in Galați, Romania.

## Multigrain blends preparation and milling

Prior to blending and milling, the five cereals were cleaned and tempered in two stages, according to the procedure described by Aprodu and Banu [7]. The multigrain blends were prepared by mixing wheat + rye + hulled oat (W+R+O), wheat + rye + hulled barley (W+R+B) and wheat + rye + triticale (W+R+T) in three different ratios of 80:10:10, 70:15:15 and 60:20:20.

The multigrain milling was performed using the Buhler laboratory mill MLU (Buhler, Uzwil, Switzerland), which includes three breaks (Br1, Br2, Br3) and three reduction rolls (C1, C2, C3), with the following technical parameters: rolls dimensions - diameter 130 mm, width 40, 90 and 70 mm in case of Br1 and C3, Br2 and C1, and Br3 and C2, respectively; roll flutes of breaks rolls - 7, 8, 9.5 per cm; rolls speed - 934 rpm. The streams resulting from the break passages were sifted through sieves with aperture size of 646 and 132  $\mu\text{m}$ , whereas the streams from the reduction passages were sifted through sieves of 646 and 132  $\mu\text{m}$ . Finally, eight meal streams were collected as follows: six flour fractions, one bran fraction (B) and one short fraction (S).

## Methods

The proximal composition and antioxidant properties of the mill streams were determined as follows: moisture (SR ISO 71:2005) [8], ash (SR ISO 2171/2002) [8], wet gluten (SR ISO 5527:2002) [8], protein (semimicro-Kjeldahl method, Raypa Trade, R Espinar, SL, Barcelona, Spain), crude fiber (Fibretherm Analyser, C. Gerhardt GmbH & Co. KG, Germany), total phenolic content (Folin-Ciocalteu method described by Singleton and Rossi [9] and modified by Gao et al. [10]), 2,2-diphenyl-1-picrylhydrazyl radical scavenging activity (DPPH-RSA, method of Brand-Williams et al. [11] and modified by Beta et al. [12]). The colour parameters (brightness ( $L^*$ ) and yellowness ( $b^*$ ) values) of the mill streams were measured using Chroma Meter CR-410 (Konica Minolta Business Solutions Europe GmbH).

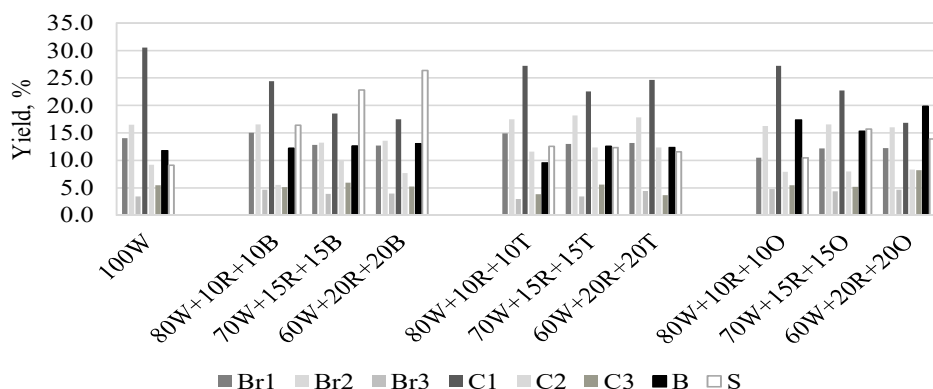
## Statistical analysis

The experiments were conducted in triplicate and the results are reported as mean values.

## RESULTS AND DISCUSSION

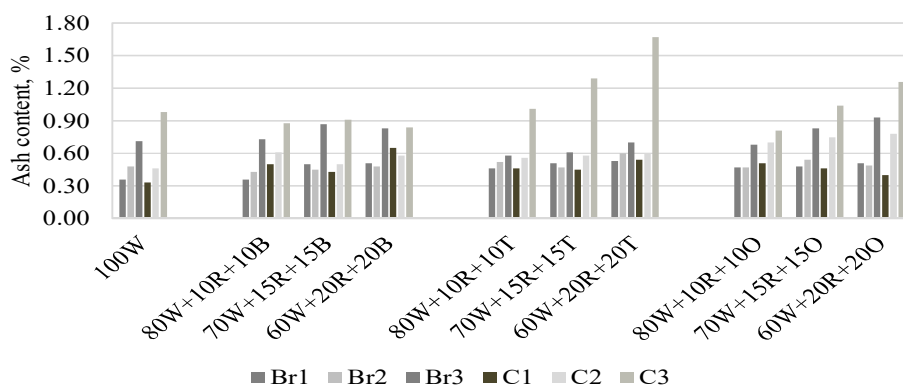
The yields obtained through multigrain milling of the three cereal blends are showed in Figure 1. The yields of the wheat flour streams from the break passages were found to gradually increase in the following order: Br3 < Br1 < Br2. The same trends can be observed in case of the multigrain flour streams collected from the break rollers (Figure 1). However, in case of the multigrain blends with hulled barley addition, the yields of the mill streams from Br2 and Br1 were close, while in case of the multigrain blends with triticale and hulled oat higher differences were found between the yields of the mill streams from Br2 and Br1. The yields of flours streams from the reduction passages of all investigated samples decreased from the first (C1) to last passage (C3) (Figure 1).

The differences, in terms of yields, between flour streams from C2 and C3 were smaller in case of the blends with hulled barley and hulled oat, compared to the wheat sample or blends with triticale addition. Similar observations were reported by Tulse et al. [13] in case of the multigrain blends consisting of wheat, green gram and barley.



**Figure 1.** Yields of mill streams resulted from multigrain milling

The relationship between yields of short and bran varied with the type of milled grain sample. A lower yield of the short was obtained in case of milling wheat sample, the yields of bran and short were rather close in case of blends with triticale, while in case of milling blends with hulled barley, the yields of short were much higher than of bran. Moreover, the yields of short and bran resulted from multigrain milling were higher compared to the wheat. We may therefore consider that the break rolls are insufficient for scraping the endosperm from the bran, and an important part of endosperm remained attached to the bran. Moreover, the reduction rolls are insufficient for decreasing the size of the endosperm particles, which are partly refused by sieving into shorts. The ash contents of the mill flour streams increased from Br1 to Br3, and from C1 to C3 (Figure 2).

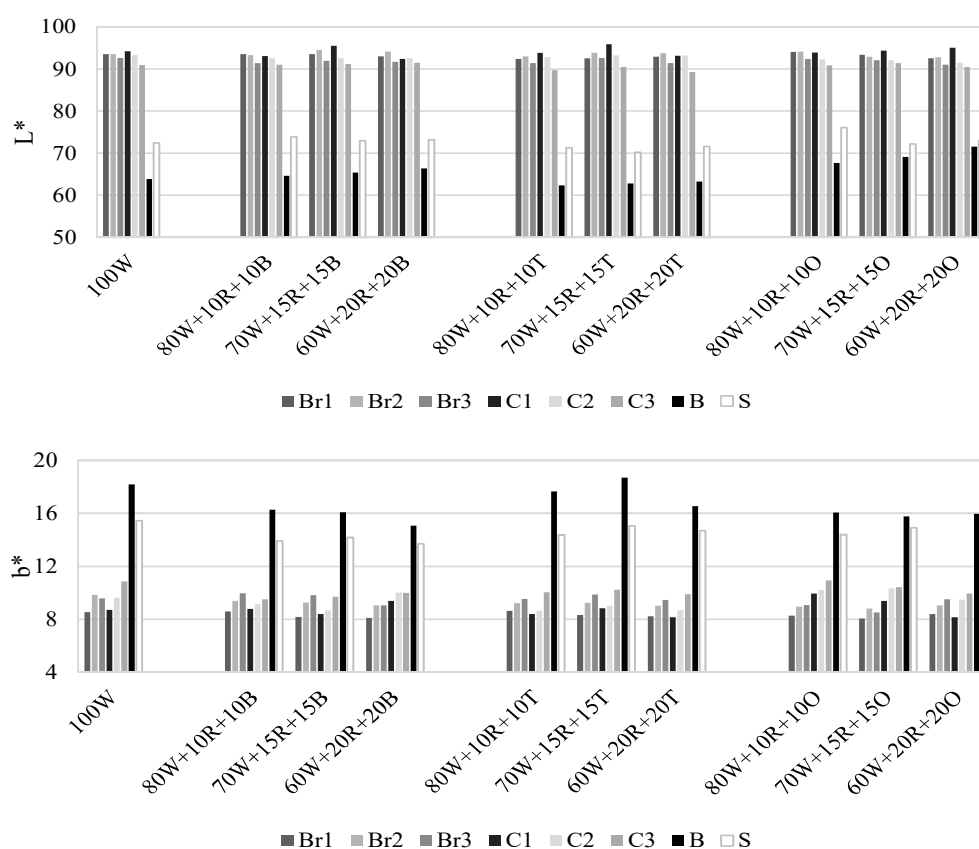


**Figure 2.** Ash contents of mill streams resulted from multigrain milling

However, in case of the multigrain blends with hulled oat, the differences in terms of ash contents between Br1 and Br2 mill streams flours are close. Moreover, similar ash contents were found for Br1 - Br2 and C1 - C2 mill streams, obtained by milling multigrain blends with 15 and 20 % hulled barley. The flour streams from C3 had very high ash content. Regardless of the mill used for processing cereals, the last flour

streams have the highest ash content. Our results are in agreement with Tulse et al. [13] who reported that the ash content increase from C1 to C3 when milling blends consisting of wheat, green gram and barley.

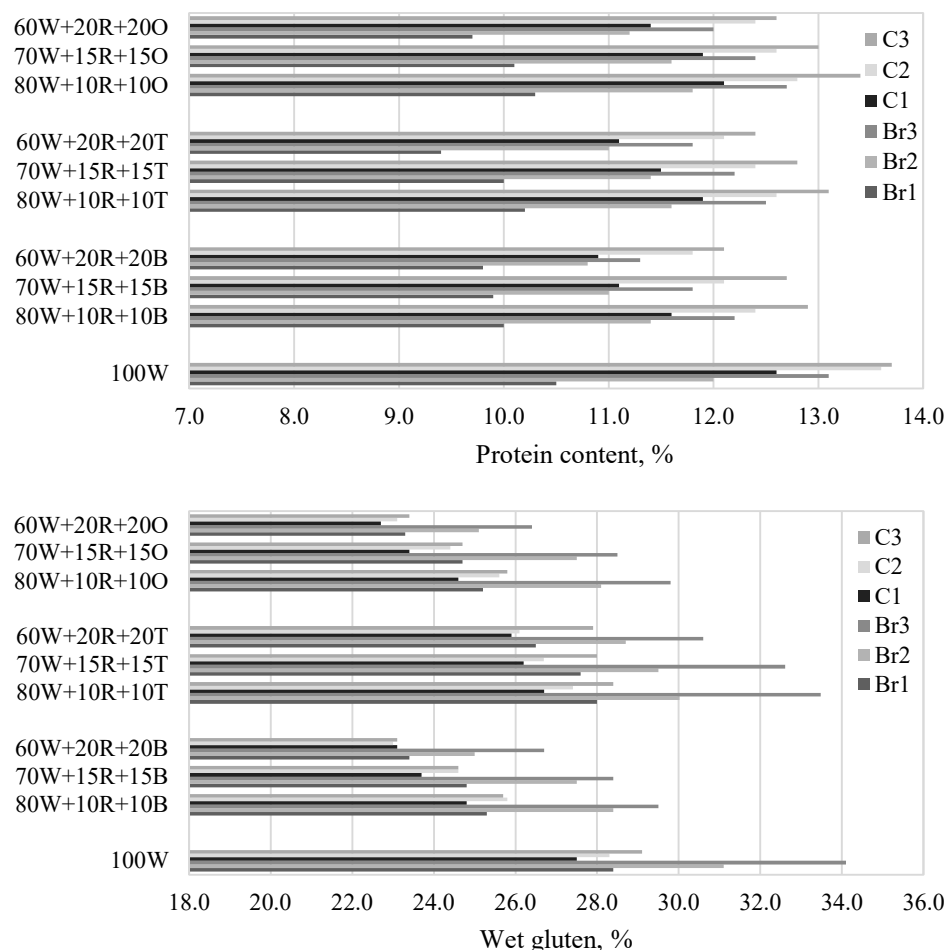
In Figure 3 are shown the brightness ( $L^*$ ) and yellowness ( $b^*$ ) values of all streams obtained by multigrain milling of the investigated blends. The trend of variation of  $b^*$  values is the same as that registered for the ash content. On the other hand the trend of  $L^*$  values is reverse when compared to the ash contents. The bran resulted from multigrain milling of blends with hulled oat and hulled barley had lower values than bran resulted by milling wheat or blends with triticale. Most probably this happened because the outer layers, that contain pigments, were removed during decortication. The  $b^*$  values of short had lower values than bran. Similar observation was previously reported by Tulse et al. [13].



**Figure 3.** The brightness ( $L^*$ ) and yellowness ( $b^*$ ) values of mill streams resulted from multigrain milling

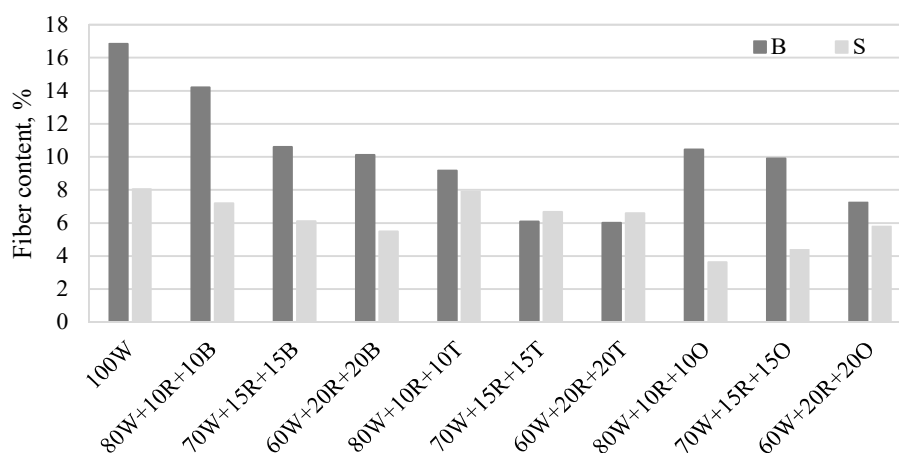
The flour streams collected from the reduction passages (C1, C2 and C3) had higher protein contents than the flour streams resulted from the break passages (Br1, Br2 and Br3) (Figure 4). All flour streams from multigrain milling had lower protein contents than wheat flour streams. Moreover, the wet gluten contents of mill streams resulted through multigrain milling were lower than of mill streams collected from wheat milling (Figure 4). This trend is due to the gluten dilution effect, through substituting the wheat with rye, triticale, hulled oat and hulled barley [14]. The streams collected from break

passages had higher wet gluten contents than those resulting from the reduction passages.



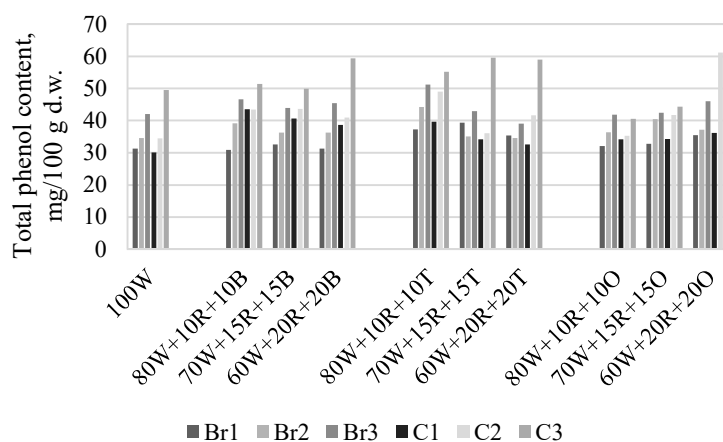
**Figure 4.** The protein and wet gluten content of mill streams resulted from multigrain milling

The fiber contents of the bran and short streams are presented in Figure 5. Wheat milling resulted in bran with higher fiber content than short. Similar results were observed in case of multigrain milling of blends with hulled barley and hulled oat. Analyzing the results presented in Figure 5 one can see that, when milling blends with increasing levels of rye, hulled oat and hulled barley, the fiber contents from bran and short were increasingly close. Regarding the triticale based samples, increasing the level of wheat substitution resulted in shorts with increasing fiber contents and brans with decreasing fiber contents. This distribution of the fibers in the streams obtained when milling triticale based blends might be explained by the higher degree of grinding at the break rolls compared to others blends based on hulled barley and hulled oat. As a consequence parts of kernel components which are rich in fiber get into the short. This explanation is supported by the yield values of short and bran obtained in case of multigrain milling of blends with triticale addition (Figure 1).



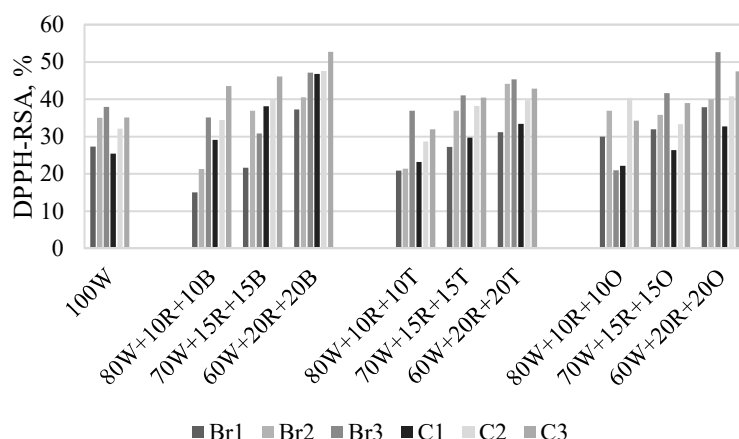
**Figure 5.** Fiber content of bran and short mill streams resulted from multigrain milling

In Figures 6 and 7 are shown the total phenol contents (TFC) and DPPH-RSA of the investigated mill streams. Overall, the TFC and DPPH-RSA of mill streams resulted through multigrain milling were higher compared to the correspondent mill streams resulted from wheat milling. The refined flours have lower TFC values compared to the streams containing the pericarp and aleurone layers which are rich in TFC and antioxidant compounds [15 – 17].



**Figure 6.** Total phenol contents of mill streams resulted from multigrain milling

Regardless of the mill stream, lower TFC values were obtained for samples with hulled oat compared to the blends including triticale and hulled barley. Analysing the results presented in Figure 6 one can see that the TFC increased from Br1 to Br3 and from C1 to C2. However, in case of mill streams resulted through milling the blends with 15 and 20 % triticale addition the TFC of Br1 was higher than of Br2, while in case of blends with 20 % hulled oat the TFC of C2 was higher than of C3. The flour streams collected from Br1 when milling the blends with hulled oat and hulled barley had TFC values close to the control which consists of wheat.



**Figure 7.** DPPH-RSA of mill streams resulted from multigrain milling

Regarding the antioxidant activity of different cereals, Zielinski and Kozłowska [18] reported the following order: barley > oat > wheat > rye. Analysing the results from Figure 7, one can see that the mill streams resulted from milling the blends with barley and oat had overall higher DPPH-RSA values compared to the correspondent streams resulted when milling wheat or triticale containing blends. The highest DPPH-RSA values were registered for mill streams obtained by multigrain milling of blends with 20 % hulled barley, triticale and hulled oat (Figure 7). The Br1 and Br2 mill streams resulted by milling blends with 10 % hulled barley and triticale, respectively, and the Br3 and C1 mill streams resulted from the 10 % hulled oat containing sample, had lower DPPH-RSA values than the corresponding mill streams resulted through wheat milling.

## CONCLUSIONS

Compared to the wheat milling, the yields from the first reduction passage decreased, while the yields of the bran and short increased in case of milling all multigrain blends. The ash contents of mill streams resulted through milling the multigrain blends increased with the increase of the wheat substitution level by other cereals. Concentration of the ash in the flour fractions collected from the third reduction passage was observed in case of blends with triticale addition. The wet gluten content decreased in flours streams with triticale, hulled barley and hulled oat addition because of the gluten dilution effect obtained when substituting wheat by other cereals. With increasing the levels of triticale, hulled barley and hulled oat in the blends, the fiber content of the bran and short became equilibrated, compared to the wheat bran that had higher fiber content than short. The milling fractions obtained by milling multigrain blends had high total phenol contents. The mill streams obtained from the multigrain blends with 20 % hulled barley, triticale and hulled oat had the highest DPPH-RSA values.



## ACKNOWLEDGMENTS

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