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INFLUENCE OF TEMPERING MOISTURE ON THE MILLING POTENTIAL OF SOME CEREALS

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Milling behavior of hulled barley and oat, triticale, rye and wheat was studied at different tempering moisture. Milling was performed using a laboratory four-roller mill. The physicochemical and technological properties of cereals and corresponding flours obtained by milling were analyzed. Milling yields, as well as protein, ash and crude fiber contents of flour were higher at lower tempering moisture in the case of all investigated cereals. In addition, tempering moisture influenced the termo-mechanical properties of the flour based doughs. The largest milling yield variation while increasing the moisture tempering between 13 and 15% was registered in the case of rye milling, whereas the largest ash content variation was registred in the case of flour obtained through hulled barley milling. The crude fiber content of hulled oat flour was much higher compared to the other investigated flours, and varied with the moisture tempering, ranging between 73.3 and 34.3% of grain crude fiber. Concerning the protein content, the largest decrease at milling was reported in the case of rye flour. Thermo-mechanical properties of doughs were affected by the level of crude fiber and the level of amylase activity. The hulled barley and hulled oat flours had higher maximum viscosity during heating, while rye and hulled barley flours had lower hot gel starch stability than wheat flour.

Keywords: wheat, rye, triticale, hulled barley, hulled oat, tempering moisture, roller mill

Introduction

The importance of cereals to world food security is well known. The main way to process cereals consists in converting them into flour using the roller mill. By this type of processing, the grains are broken gradually so that the endosperm is separated from bran layers and germ. Endosperm consists of starchy endosperm and aleurone layer. Generally, the starchy endosperm is ground into flour, while the aleurone layer, bran layers and germ are separated as bran (Dewettinck *et al*., 2008). The conditioning process has a key role in influencing the participation of the anatomical components of kernel in the flour and bran (Tulse *et al*., 2014), and further the milling yield, as well as the functional and nutritional properties of end-use products.

Conditioning process facilitates the separation of the starchy endosperm from the rest of the parts of kernel, by creating the intern tensions between different layers of kernels. The kernel breaks in the areas where internal tensions occur. The cereals have different composition and different textures of the endosperm, so the behavior of kernel during milling varies with the different tempering regimes. Moreover, the milling mechanism influences how kernel braking occurs (Doehlert and Moore, 1997). Therefore, for every cereal and every milling mechanism it is necessary to establish the optimal tempering moisture. There is little information available regarding the influence of conditioning step applied to the triticale, hulled barley and hulled oat prior to milling through a roller mill. According to Dennett and Trethowan (2013), the efficiency of triticale milling with Brabender Quadrumat Jr decreased when increasing the tempering moisture from 11 to 15%. Doehlert and Moore (1997) reported that tempering the oat at 12% moisture for 20 min prior to milling with Brabender Quadrumat Jr resulted in higher bran yield with higher protein and β-glucan contents. Kiryluk et al. (2000) reported for barley milling the increase of grits yield and their β-glucans contents with moisture increase from 10 to 14%, during dry milling in a laboratory-scale. Moza and Gujral (2017) noted that tempering the hulless barley at 14% moisture for 30 min prior to milling in Brabender Quadrumat Jr facilitated refined flour with good quality.

The objective of our investigation was to study the behavior of wheat, rye, triticale, hulled barley and hulled oat at different tempering moistures at roller milling. The physicochemical and technological properties of cereals and of the flours obtained by milling were analyzed.

Materials and methods

Wheat, rye and triticale grown in South East Romanian Plain harvested in 2016, and commercial hulled barley and hulled oat purchased from the local market (Galaţi, Romania) were used in this study.

Samples tempering and milling

Cereal samples were tempered to 13, 14 and 15% moisture in two stages: in the first stage 2/3 of all water quantity was added onto grains, followed by 8 hours of resting; in the second stage the rest of the water was added, followed by a resting period of 4 hours prior to milling.

Milling was performed using a laboratory four-roller mill type SK (Sadkiewicz Instruments, Poland), with the following technical features: number of grooves in rollers 5; 10; 14; 16 per cm; roller diameter 71 mm, width 30 mm; 980 rpm for roller 1 and 3, 450 rpm for roller 2 and 4. After milling, products were sieved using 500 and 315 μm sieves, resulting in bran, short and flour, respectively.

Physicochemical analysis

The cereals and flours were analyzed for ash content with SR ISO 2171 method (ASRO 2008), moisture content using the AACC 44–51 method (2000), protein content using semimicro-Kjeldahl method, and crude fiber using Fibreterm system (Gerhardt Analytical Systems). Test weight and thousand kernel weight were determined according to SR ISO 7971-2:2002 and SR ISO 520:2002, respectively. Sharpness module was determined according to Godon and Willm (1994) through sieving the flour using 250, 180, 160, 125 and 90 µm sieves. The initial water absorption rate, water absorption index and moisture saturation point were measured according to the methods described by Buffo *et al.* (1998).

The milling efficiency of the cereals (R) and ash index value of flour (AIVF) were determined according to Moraru (Aprodu and Banu, 2016).

Color characteristics (L*, b*) of flours were measured with Chroma Meters CR-400 / CR-410 (Konica Minolta).

Thermo-mechanical properties

Thermo-mechanical properties of cereals and flours were measured using Chopin Mixolab device (Chopin Technologies, Villeneuve La Garenne, France) and Chopin+ protocol, according to ICC 173 method (2011).

Statistical analysis

All experiments were conducted in triplicate and mean values were reported. In order to identify the significant differences between experiments, the analysis of variance was used.

Results and discussion

Physicochemical characteristics of grains

The investigated cereals had comparable moisture contents (Table 1), ranging between 11.6 and12.7%. Among all samples, the highest test weight (TW) and thousand kernel weight (TKW) values were observed in the case of wheat (TW of 80.6 kg/hl and TKW of 40.7 g). Based on the protein and crude fiber contents of 13.4 and 3.6%, respectively, it can be stated that the wheat sample used in the experiment had high quality. Rye had lower TKW (28.4 g) and protein content (9.8%) compared to wheat and triticale (Table 1). The hulled oat had the highest ash and protein contents, and the lowest TW and TKW weight, most probably because of its high degree of decortication.

The water absorption properties of the grains over 8 hours of steeping at 30°C are presented in Figure 1. The initial water absorption rate (IWAR) was estimated as the grain weight increased after 0.25, 0.50, 0.75 and 1 hours of steeping (Buffo *et al.*, 1998). Analyzing the results presented in Figure 1 one can see that the lowest IWAR values were registered in the case of wheat sample (12.3%), while the highest in the case of hulled barley (28%). Triticale, rye and hulled oat had similar values for IWAR of 19, 19.6 and 20.9, respectively. Buffo *et al*. (1998) reported a positive correlation between IWAR and starch content. They considered that, because of the physicochemical particularities, starch generates a lower driving force for water uptake compared to other components, and, as a consequence, IWAR is lower. On the other hand, it is known that barley, rye and oat have higher amounts of pentosans and β-glucans than wheat (Godon and Willm, 1994). Water absorption index (WAI) values, estimated after 2 hours of steeping, presented higher variability among the investigated cereals, ranging from 17.5 (wheat) to 37% (hulled barley). Moisture saturation point (MSP), defined as the maximum amount of water absorbed before the appearance of ruptures in outer the layer of the grains (Buffo et al., 1998), was very close for rye, triticale and hulled oat kernels (30-31.2%). Hulled barley kernel had the highest value of MSP of 47.2%, while wheat kernel had the lowest value of 23.3%.

Table 1. Physicochemical characteristics of grains

Samples	Moisture, %	Test weight, kg/hl	Thousand kernel weight, g	Ash content, %	Protein content, %	Crude fiber content, %
Wheat	11.6	80.6	40.7	1.65	13.4	3.6
Rye	12.3	77.0	28.4	1.75	9.8	3.6
Triticale	12.7	75.2	37.6	1.85	12.5	3.7
Hulled barley	12.2	78.3	38.0	1.28	11.2	4.4
Hulled oat	12.2	71.5	18.9	1.92	13.8	2.1

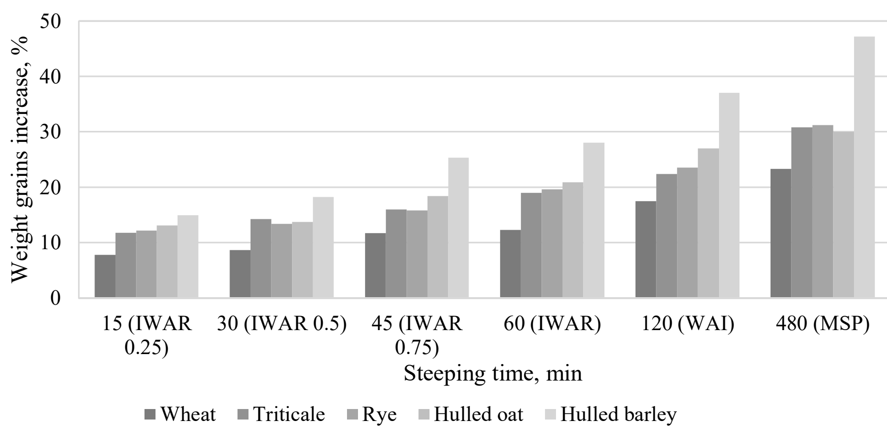

Figure 1. Water absorption properties of the grains over 8 hours of steeping (WAI - water absorption index, IWAR - initial water absorption rate, MSP - moisture saturation point)

The milling yield was significantly influenced by the tempering moisture ($p<0.05$). Analyzing the results presented in Figure 2a, one can see that, regardless of the investigated cereal, the highest milling yields were obtained at the lowest tempering moisture. The narrowest variations of the milling yield for the same cereal at different tempering moisture were found in the case of wheat, triticale and hulled oat. In the case of rye, the milling yield varied considerably with the tempering moisture considered in our investigation.

Milling efficiency was analyzed by R coefficient and the ash index value of flour. The R coefficient measures the cereal potential to achieve a milling yield of flour with low ash content, whereas the AIVF highlights the quality and milling yield of flour. Regardless of the investigated cereal, the R value increases whereas the AIVF decreases when increasing the moisture content from 13 to 15% ($p<0.05$) (Table 2). Anyway, particular behavior has been noticed for each investigated cereal.

Wheat had the highest R coefficient of 254 at 15% tempering moisture, and higher differences were observed when passing from 14 to 15% moisture, with respect to the 13 and 14 % moisture. A similar trend was observed in the case of AIVF, which decreased from 843 at 13% moisture, to 776 at 14% and further to 649 at 15% moisture. It can be therefore considered that optimum tempering moisture in the case of wheat is 15%.

Table 2. Milling indices of grains

Samples	Tempering moisture, %					
	13		14		15	
	AIVF	R	AIVF	R	AIVF	R
Wheat	843	196	776	213	649	254
Rye	1880	93	1453	120	1387	126
Triticale	1156	160	1028	180	983	188
Hulled barley	2177	59	1965	65	1840	70
Hulled oat	2085	92	1960	98	1881	102

The R coefficient and AIVF of rye and triticale registered the highest differences when increasing the tempering moisture from 13 to 14%. Based on these results, one can appreciate that the optimum tempering moisture in the case of rye and triticale is 14%.

According other studies, the tempering moisture recommended for rye milling is by 1-1.5% lower than wheat, after a tempering time of about 6-15 hours (Lorenz, 2000, quoted by Dennett and Trethowan, 2013). Dennett and Trethowan (2013) studied the milling efficiency of triticale grain with different hardness and noted that the milling efficiency decreased at moisture increase from 11 to 15%. They also reported that milling efficiency was negatively influenced by kernel hardness and ash content. Compared to wheat, Dennett and Trethowan (2013) reported 7.1-10.1% lower milling efficiency in the case of triticale. The authors mentioned that triticale could behave similarly to hard wheat or even durum, due to the secaloindolines from the rye genome (Li *et al*., 2006). On the other hand, there is a triticale variety with lower hardness. The milling efficiency decreased with moisture increase from 11 to 15%. In particular, in the case of hard variety (grain hardness over 70) the yield flour decreased from 57% to 40% whereas the ash content from 1.07% to 0.91%. In the case of soft Triticale variety (grain hardness 36.22) the flour yield was 65% and ash 0.80% at 11% moisture, and decreased to about 55% and 0.65%, respectively at 15% moisture content. The hardness of the triticale used in our study was higher compared to rye and wheat as evidenced by the granularity and modules of flour particles (Figure 2c).

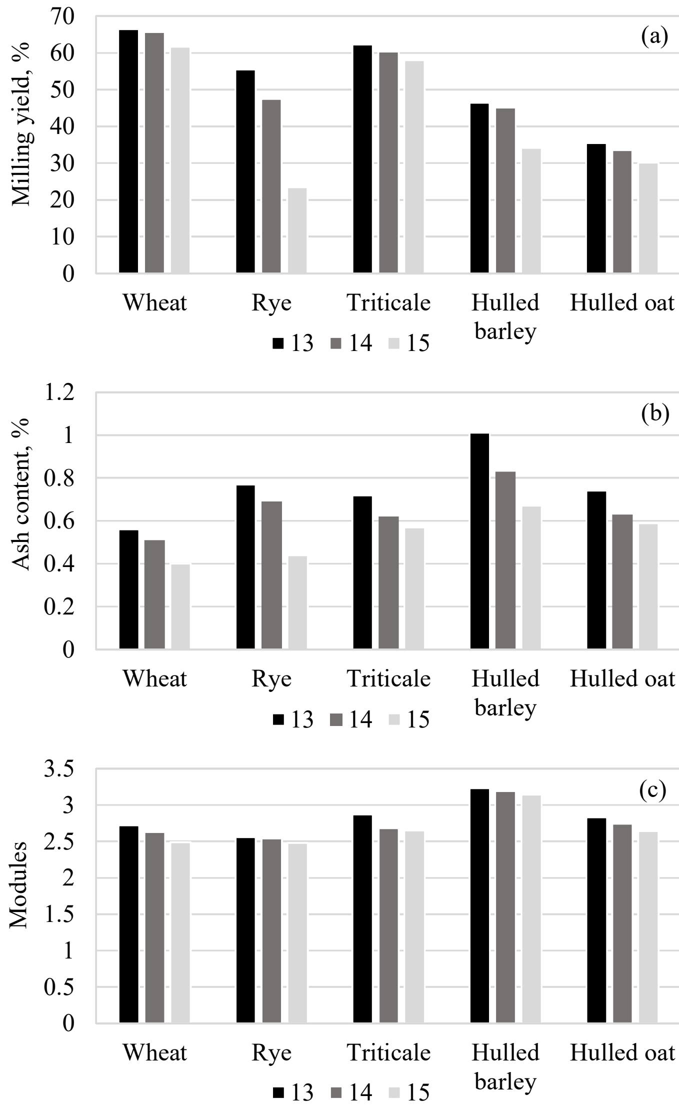

Figure 2. Milling properties of cereals: milling yield (a), ash content (b), modules (c)

The R coefficient and AIVF of hulled barley and hulled oat registered the same differences between 13 and 14% tempering moisture as between 14 and 15%. (Table 2). Taking into account these results but also the differences in terms of milling yield (Figure 2a), ash content (Figure 2b) and modules of flour particles (Figure 2c) resulting at different tempering moisture, one can consider that the optimum tempering moisture in the case of hulled barley is 14%, and in the case of hulled oat is 13%.

Regardless of the investigated cereal, lower contents of crude fiber were obtained at higher tempering moisture (Figure 3a). The crude fiber content retained by the wheat, rye, triticale and hulled barley flours with respect to the amounts available in the cereals ranged between 43.3-48.9% at lower tempering moisture (13%), and between 24.2-27.5% at higher tempering moisture (15%) (Figure 3a). Regardless of the tempering conditions, larger amounts of grain crude fiber were retained in the flour in the case of hulled oat flours, namely 73.3% at tempering moisture of 13% and of 34.3% at 15%.

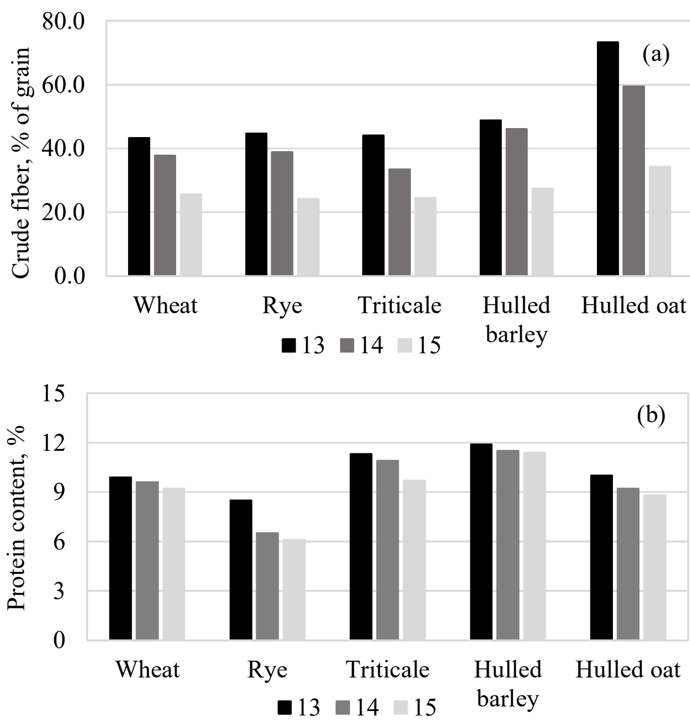

Figure 3. Protein content (a) and ratio of crude fiber retained by the flour with respect to the initial grain (b) for the investigated flours

Flores *et al.* (2005) analysed the milling process of hulled barley using different experimental mills – Chopin CD1, Quadrumat Sr and Buhler MLU-202, in different tempering conditions. The results indicated that milling yield, protein content and β-glucans content depend on the type of experimental mill, tempering moisture and barley variety. Short fractions had the highest protein and β-glucans contents, while break flours had the lowest protein and β-glucan contents.

Doehlert and Moore (1997) reported that tempering oat to 12% moisture for 20 min represents the optimum condition for obtaining oat bran using roller mill. Oat bran had 8.57 % β-glucans, 22.1% proteins, and 3.74% ash content, while fine flour had 1.25% % β-glucans, 11.1% proteins and 0.8% ash content (Doehlert and Moore, 1997). Higher bran yields were obtained at higher moisture and shorter tempering times.

Regardless of the investigated cereal, the protein content decreased as the tempering moisture increased (Figure 3b). Similar findings were reported by other studies, such as Doehlert and Moore (1997) and Dennett and Trethowan (2013). The largest decrease was observed in the case of rye.

The color characteristics, namely brightness value (L*) and yellowness value (b*), of the flours obtained through roller milling the cereals are presented in Table 3.

In the case of all investigated cereal, the L* values increased for flour samples and the ash content decreased (Figure 1b) when raising the tempering moisture. The smallest variation of L* values over the tested tempering moisture interval was registered for hulled oat (Table 3).

Yellowness value decreased with the tempering moisture increase (Table 3), and hulled oat flour had b* values very close to wheat flour.

The thermo-mechanical properties of flour measured with Mixolab device are shown in Figure 4.

Table 3. Brightness value (L*) and yellowness value (b*)

Samples	Tempering moisture, %					
	13		14		15	
	L*	b*	L*	b*	L*	b*
WF*	88.4	11.1	90.1	10.9	91.5	10.8
RF	85.7	10.2	85.8	9.9	88.6	9.6
TF	89.1	10.8	90.7	9.6	91.9	9.4
HBF	86.0	9.0	86.9	8.6	89.0	8.1
HOF	87.1	11.1	88.3	10.0	88.4	10.1

*WF – wheat flour, RF – rye flour, TF – triticale flour, HBF – hulled barley flour, HOF – hulled oat flour

The tempering moisture increased from 13 to 15% resulting in flours with lower values of the minimum torque C2, which defines protein weakening induced by increased temperature and kneading. The lowest C2 values were reported in the case of hulled oat flours (0.21-0.25 Nm), while the highest values were reported in the case of hulled barley flours (0.58-0.63). The maximum viscosity during heating (C3), which measures starch gelatinization, was higher in the case of hulled barley and hulled oat flours at lower tempering moisture (13%). This behavior might be associated to the higher crude fiber content found in these flours (Figure 3b). Bhatty and Rossnagel (1998) reported that the addition of barley middlings into wheat flour increased the peak viscosity and setback, due to the increase of β-glucan level. The lower values of C4, that measures hot gel starch stability, registered in the case of rye and hulled barley flours can be attributed to the high amylase activity (Dubat and Boinot, 2012). The starch retrogradation values (C5-

C4) were lower for the rye, triticale, hulled barley and hulled oat flours than for the wheat flour, due to the different properties of starches.

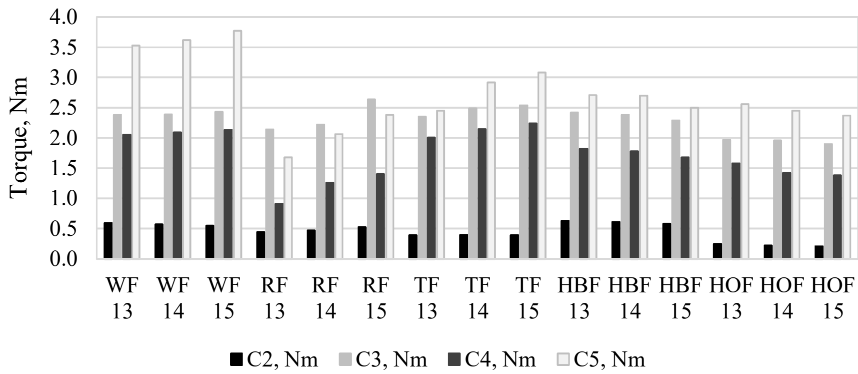

Figure 4. Thermo-mechanical properties of flours measured with Mixolab device (C2, C3, C4 and C5) WF – wheat flour, RF – rye flour, TF – triticale flour, HBF – hulled barley flour, HOF – hulled oat flour

Conclusions

Milling efficiency of hulled barley, hulled oat, triticale, rye and wheat depends on the tempering moisture prior to milling. The differences in terms of milling yield between different tempering moisture are not the same for all investigated cereals. Similar variation of the ash index value of flour in the case of hulled barley and hulled oat registered was registered when passing from 13 to 14 and then to 15% tempering moisture. In the case of rye and triticale, higher variation of the ash index value of flour was found between 13 and 14% tempering moisture. The tempering moisture also influenced the protein and crude fiber contents of flours and the thermo-mechanical properties of dough made of these flours. A large amount of crude fiber (73.3%) was found in oat flour at lower tempering moisture (13%), while in the case of wheat, rye, triticale and barley flours, in the same moisture conditions, the crude fiber contents ranged from 43.3 to 48.9% of grain. The protein content decreased as tempering moisture increased. In the tempering condition considered in our work, the largest decrease was observed in the case of rye. The high level of crude fiber from hulled barley and hulled oat flours resulted in higher maximum viscosity during heating. On the other hand, the high level of amylase activity caused the decrease of the hot gel starch stability of rye and hulled barley flours.

Acknowledgments

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