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COMPARATIVE ANALYSES OF PHYSICOCHEMICAL AND TECHNOLOGICAL PROPERTIES OF TRITICALE, RYE AND WHEAT

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Wheat, rye and triticale samples were evaluated in terms of physicochemical and technological properties. The triticale samples had higher susceptibility of sprouting compared to rye. The milling value of wheat and triticale samples was over 70, suggesting good milling properties and the ability to provide flours with low extraction rates. Of all studied grains, triticale had the lowest dough development time, dough stability and weakening. The gluten network formed by glutenin and gliadin fractions from triticale was weak and the dough had insufficient plasticity, being therefore difficult to process. Rye is a good source of soluble dietary fibers, followed by wheat and triticale. The antioxidant properties of cereals were evaluated on the basis of 2,2-diphenyl-1-picrylhydrazyl radical scavenging activity and Trolox equivalent antioxidant capacity. The rye samples had the highest antioxidant properties, followed by triticale and wheat. The physicochemical and technological properties of triticale suggest that this cereal can be successfully used in composite flours as ingredient for obtaining different baked products.

Keywords: triticale, rye, wheat, physicochemical properties, technological properties, dietary fiber, antioxidant activity

Introduction

Triticale is a hybrid of wheat and rye, and is considered a potential alternative to wheat for different bakery products (Dennett and Trethowan, 2013). In agreement with Jonnala *et al*. (2010), triticale combines the most important properties of the wheat and rye grains, such as the high yield potential and grain quality of wheat, and the resistance to pathogens of rye. Chapman (2005) showed that the yield of this grain is competitive with the highest yielding wheat varieties. According to Darvey *et al*. (2000), the main differences between physical properties of triticale and wheat are grain size and thousand kernel weight, triticale having longer grain and higher thousand kernel weight. The milling value of triticale is strongly influenced by the texture of grain and tempering moisture. Thus, Dennett and Trethowan (2013) noted that the milling yield and protein content of triticale flour were higher at lower tempering moisture, and the flour ash content was higher with respect to wheat. At the same tempering condition, Dennett & Trethowan (2013) obtained higher flour to bran ash ratio for triticale compared to wheat. The authors appreciated that the larger surface area of triticale grain could be responsible for milling behavior.

Anderson *et al*. (1972) showed that triticale offers more diverse nutrients to humans than wheat and has higher protein and fiber contents. Based on amino acid composition, especially lysine, Chapman (2005) noted that the triticale protein is of high quality. Triticale has high total phenolic contents (Jonnala *et al*. 2010), out of which ferulic and p-cumaric acids represent more than 90%. Similar composition of phenolic acids was reported by Andreasen *et al.* (1999) for rye.

The aim of the present study was to compare the physicochemical and technological properties of three different grains: triticale, wheat and rye.

Materials and methods

Materials

The study was focused on four samples of common wheat bread, four samples of rye, and four samples of triticale purchased from Galati market (Romania).

The physicochemical and rheological tests were performed on the wholemeal flours obtained by milling the grains by means of Perten laboratory mill 120 (Perten Instruments AB, Hägersten, Sweden). After milling, all samples were cooled and stored in refrigeration conditions until analysis.

All reagents used in the experiments were of analytical grade.

Physicochemical analysis

The analyses of physicochemical properties included: moisture content (AACC Method 44-51), test weight (ASRO 2008; SR ISO 7971-2:2002), 1000-kernel weight (ASRO 2008; SR ISO 520:2002), vitreous kernel (method of Godon and Willm (1994) based on the use of farinotom), ash content (ASRO 2008; SR ISO 2171/2002), protein content (ICC 159) using Inframatic model 8600 (Perten Instruments AB) and falling number (AACC 56-81B) using Falling Number model 1400PT (Perten Instruments AB).

For each type of grain, the milling value (MV) was calculated using the equation proposed by Moraru (1988):

$$MV = 4 \cdot (TWK - 27) + 100 \cdot (2 - A) \qquad (1)$$

where *TWK* is the 1000-kernel weight, and A is the ash content.

The quantification of different functional compounds was performed on the whole wheat flour and included: total, insoluble and soluble dietary fiber contents assessed using a method that combines enzymatic and gravimetric principles (Asp *et al.*, 1983) (Merck KGaA, Darmstadt, Germany), total phenolic contents (method of Singleton and Rossi (1965), and modified by Gao *et al.* (2002)), 2,2-diphenyl-1-picrylhydrazyl radical scavenging activity (method of Brand-Williams *et al.* (1995), and modified by Beta *et al*. (2005)) and Trolox equivalent antioxidant capacity (method of Re *et al.* (1999), and modified by Villauenga *et al*. (2009)).

Analysis of technological properties

The technological properties of whole wheat flours were tested with Chopin Mixolab device, using the Chopin+ and Chopin S protocols, according to ICC 173 method (2011).

Statistical analysis

All measurements were performed at least in duplicate and the statistical analysis of the results was accomplished by means of Excel software.

Results and discussion

Physicochemical properties

The average value of thousand kernel weight for the triticale samples was 40.2 g, about 24% higher with respect to the rye samples, and closer to the wheat samples (Table 1). The average of vitreous kernel was 36.8%, about 20% higher than the average of the rye samples, and about 5% lower than the average of the wheat samples. Moreover, the average value of test weight for the triticale samples was 74 kg/hL, in between the wheat and rye samples (Table 1). These results can be explained by the differences between wheat, rye and triticale in terms of grain size and density. The rye kernels had lower size and the endosperm was less compact compared to wheat and triticale kernels. Our results comply with other studies. Du Pisani (2009) mentioned TKW values of 35-55 g for triticale, and softer texture compared to wheat. Dogan *et al.* (2009) reported for triticale average values of 44.68 g and 69.54 kg/hL for TKW and TW, respectively.

Table 1. The physicochemical parameters of the investigated wheat, rye and triticale samples

	Wheat samples		Rye samples		Triticale samples	
	Mean	CV, %	Mean	CV, %	Mean	CV, %
Test weight, TW (kg/hL)	79	1.00	72.2	1.06	74	1.46
1000-kernel weight, TKW (g)	41.7	6.04	30.3	2.79	40.2	3.80
Vitreous kernel (%)	39	9.25	29.3	6.43	36.8	3.94
Ash content (%)	1.72	3.12	1.69	2.05	1.96	3.59
Protein content (%)	11.5	1.23	10.4	5.35	11.8	2.58
Falling number, FN (s)	315	7.78	170	8.15	105	9.34
Milling value, MV	80.6	9.76	44.4	8.60	63	5.50

CV – coefficient of variation

Triticale and wheat samples had similar protein contents (average values of 11.8% and 11.5%, respectively), higher compared to the rye samples (10.4%). Anderson *et al*. (1972) reported higher contents of proteins for triticale (17%), durum wheat (15%), soft wheat (12%) and rye (13.4%).

As expected, higher values of the falling number (FN) were obtained for wheat samples (315 s) compared to rye and triticale samples. Based on this observation we can say that triticale had higher amylases activity, and higher susceptibility to sprouting compared to rye samples. According to Weidner *et al*. (1999), the cultivars resistant to sprouting have lower germination percentage than those susceptible to sprouting. In addition, the authors mentioned that rye caryopses germination was lower compared to wheat and triticale. Martinek *et al*. (2008) suggested that the European triticale varieties had high α-amylase activities and low FN values. Tayyar (2014) reported average FN values of about 210 s, while Erekul and Kohn (2006) mentioned values ranging from 62 to 180 s, with an average of 100 s. On the other hand, the FN values reported for wheat range between 200 and 250 s, while in case of rye the FN values are higher than 75 s (Bushuk, 1976).

The milling values (MV) were 80.6 in the case of the wheat samples, 63 in the case of the triticale samples, and 44.4 in the case of the rye samples. MV over 70 defines the good milling properties and the possibility to obtain, by milling, flour extraction rates with low ash contents (Moraru, 1988). The lower value for MV of rye can be explained by lower values of TKW compared to wheat and triticale. Moreover, the content of layers of the rye kernel is higher with respect to wheat kernel (Bushuk, 1976), which means that rye milling generates lower flour extraction rates.

Analysis of technological properties

The technological properties of the cereal samples were analysed using Mixolab device that measures the torque of the dough during kneading and thermal treatment. For the sake of comparison in Figure 1a and Figure 1b are shown the Mixolab curves resulted by running Chopin S and Chopin+ protocols on each cereal taken into analysis.

The water absorption (WA) of triticale samples is higher than rye and wheat, and this can be explained by the higher protein content of triticale flour with respect to wheat and rye flours (Table 2). On the other hand, the dough development time (DDT), dough stability (DS) and dough weakening (DW) values suggest that the wholegrain wheat flour had the highest protein quality, being followed by the rye and triticale samples. The low values of the indicated parameters obtained for wholegrain triticale flours, indicate that even though glutenin and gliadin fraction from triticale have the ability to form gluten network, this network is weak and the dough had insufficient plasticity, being difficult to process. The average values of DDT, DS and minimum torque (C2) for wheat (Table 2), give indications that the quality of the proteins from the wholegrain wheat flour is very good for breadmaking. According to Dubat and Boinot (2012), the wheat flour-based doughs characterized by DDT values ranging from 3 to 8 min, DS between 8 and

12 min, and C2 below 0.5 Nm have good breadmaking quality. The highest DW during kneading at 30°C (mechanical weakening) and the lowest C2 during kneading and temperature increase (mechanical and thermal constraints) were obtained for triticale dough.

Table 2. The rheological parameters of the investigated wheat, rye and triticale samples

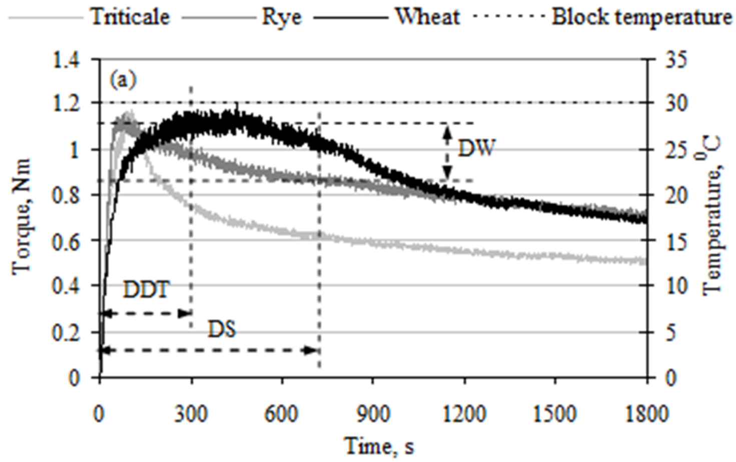
	Wheat samples		Rye samples		Triticale samples	
	Mean	CV, %	Mean	CV, %	Mean	CV, %
Water absorption, WA (%)	64.0	2.20	65.9	4.10	68.4	3.00
Dough development time, DDT (min)	8.00	12.50	2.85	9.73	2.75	12.96
Dough stability, DS (min)	12.50	6.93	6.00	11.79	2.00	9.87
Dough weakening, DW (UF*)	12.67	12.06	85.50	14.06	122.00	4.49
Minimum torque, C2 (Nm)	0.40	2.80	0.60	2.90	0.30	8.30
Starch gelatinization, C3 (Nm)	2.00	6.40	2.12	7.10	1.46	6.20
Amylase activity, C4 (Nm)	1.70	8.70	0.97	7.90	0.45	4.70
Starch gelling, C5 (Nm)	2.50	9.40	1.46	6.10	0.89	8.50
Thermal weakening, C3-C2 (Nm)	1.60	7.30	1.52	8.80	1.15	7.40
Cooking stability range, C3-C4 (Nm)	0.30	11.30	1.16	10.00	1.01	6.90
Cooling setback, C5-C4 (Nm)	0.80	21.50	0.49	9.60	0.45	18.20

* 1 Nm = 500 UF; CV – coefficient of variation

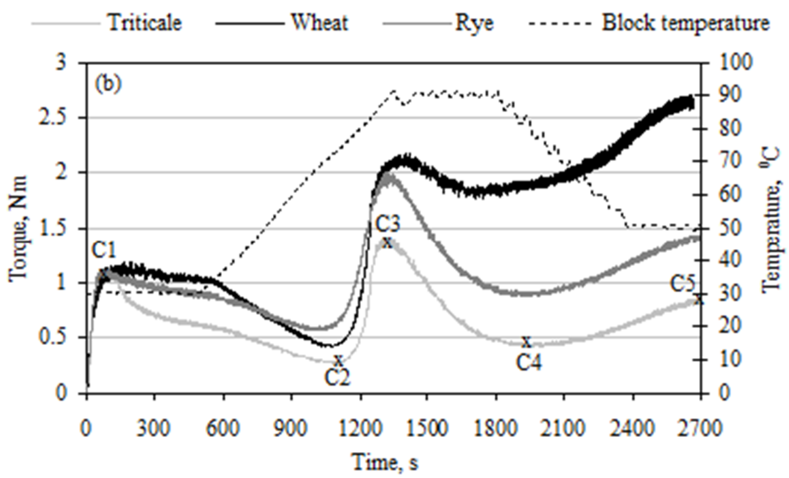
Information regarding the activity of amylolytic enzymes from the wholegrain flours, starch gelatinisation and retrogradation is given by the torque values from different zones of the Mixolab curves related to starch gelatinization (C3), thermal weakening (C3-C2), amylase activity (C4), cooking stability range (C3-C4), starch gelling (C5), and cooling setback (C5-C4). Due to higher amylase activity, the lowest values for C3, C4 and C5 were registered in the case of triticale. Compared to wheat, lower parameters were obtained for rye, due to higher amylase activity. A significant correlation ($P < 0.05$) was obtained between FN and C4 (0.98), FN and C5 (0.99). A positive correlation ($P < 0.05$) was registered between FN and C3-C4 (0.79).

Fiber contents and antioxidant properties

Total dietary fiber (TDF) of cereals decreased in the following order: rye (18.91 g/100 g d.w.), triticale (16.3 g/100 g d.w.) and wheat (15.05 g/100 g d.w.) (Table 3). The same trend was observed also in terms of soluble dietary fiber (SDF). On the other hand, triticale had the highest content of insoluble dietary fiber (IDF).



(a)



(b)

Figure 1. Mixolab curves resulted by running Chopin S (a) and Chopin+ (b) protocols for one sample of wheat, rye and triticale

Rye samples had the highest total phenolic contents (TPC) of 70.79 mg/100 g d.w., followed by triticale with 66.06 mg/100 g d.w., and wheat with 48.07 mg/100 g d.w. Our results are comparable to those reported by Weidner *et al*. (1999), although they used different investigative methods. Thus, total phenolic acids (free, liberated from soluble esters and glycosides) ranged between 50.13 and 83.16 mg/g d.w in the case of wheat, between 121.4 and 184.38 mg/g d.w. in the case of rye, and from 78.48 to 99.34 mg/g d.w. for triticale. Our results comply with the observations of Ragaee *et al*. (2006) who reported that TPC of rye is about 2 times higher compared to wheat. On the other hand, Jonnala *et al.* (2010) reported that the content of ferulic acid in triticale bran is higher with respect to rye and wheat bran.

Table 3. The fiber contents and antioxidant properties of the investigated wheat, rye and triticale samples

	Wheat samples		Rye samples		Triticale samples	
	Mean	CV, %	Mean	CV, %	Mean	CV, %
Total dietary fiber, TDF (g/100 g d.w.)	15.05	3.51	18.91	5.84	16.30	4.78
Insoluble dietary fiber, IDF (g/100 g d.w.)	12.47	2.66	14.41	4.16	14.96	4.44
Soluble dietary fiber, SDF (g/100 g d.w.)	2.58	2.21	4.50	3.12	1.34	1.77
Total phenolic contents, TPC (mg/100 g d.w.)	48.07	8.99	70.79	9.59	66.06	8.01
DPPH-radical scavenging activity, DPPH-RSA (%)	18.95	9.35	26.21	8.38	20.12	5.67
Trolox equivalent antioxidant capacity, TEAC (μmoli Trolox/g d.w.)	2.81	4.27	4.82	6.25	3.67	5.41

CV – coefficient of variation

The antioxidant properties of cereals were evaluated using DPPH-radical scavenging activity (DPPH-RSA) and Trolox Equivalent Antioxidant Capacity (TEAC) methods. Both methods indicated that the rye samples had the highest antioxidant properties (Table 3). The DPPH-RSA of the rye samples was 26.21%, about 1.3 times higher compared to triticale, and about 1.4 times higher compared to wheat. Similar differences among samples were obtained also in terms of TEAC (Table 3). Ragaee *et al*. (2006) reported higher antioxidant activity for rye compared to wheat, about 3 and 1.5 times higher in the case of DPPH-RSA and TEAC, respectively.

Conclusions

Taking into account the importance of cereals to food security, it is essential to know their physicochemical and technological properties, such as to achieve efficient composite flours. Our results indicated better milling properties and higher susceptibility to sprouting of the triticale samples compared to the rye samples. The gluten network formed by triticale proteins was rather weak and the dough appeared difficult to process. On the other hand, rye is a good source of soluble dietary fiber, followed by wheat and triticale. As far as the antioxidant properties are concerned, the rye samples had the highest activity, being followed by triticale and wheat.

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