

RESEARCH ARTICLE

Physico-chemical properties and milling behavior of modern triticale genotypes

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ABSTRACT

Triticale is a cereal crop alternative to wheat, and its incorporation into food products is limited. This work aimed to evaluate the physico-chemical properties and the milling behavior of modern triticale genotypes in order to determine their use in the baking industry. The protein content, sodium dodecyl sulfate (SDS) sedimentation test, and falling number of triticale genotypes were lower than wheat. The ash content was higher for triticales, while the test weight, starch content, and flour extraction yield were comparable to wheat; but with a considerable variability in the break and reduction flour yield. The studied triticale genotypes can be used in food products that do not require high gluten strength, such as cookies and cakes, as well as cereal bars or extruded cereals, for which ash content and falling number are irrelevant. In addition, the falling number test was not adequate to evaluate the α -amylase activity of triticales and considerable variability in the triticale grain hardness was observed.

Keywords: Bakery; Cereal; Gluten

INTRODUCTION

Modern cultivated triticales (*x Triticosecale* Wittmack) are hexaploid-type, derived from artificial crosses between tetraploid wheat (*Triticum durum*) and rye (*Secale cereale* L.). Triticale combines the most important attributes of the two parents: the superior agronomic performance and the end-use qualities of wheat with the resistance to various biotic and abiotic stresses and nutritional value of rye. Cultivated under favorable conditions, the yield of modern triticale genotypes is on a par with the best wheat cultivars and growing on marginal soils (acid, saline or heavy metal toxicity), triticale can overcome the efficiency of wheat (Ammar et al., 2004). Additionally, compared to wheat, triticale presents a better mineral balance, a higher proportion of soluble fibers, a higher content of lysine (the first limiting amino acid in cereals) and has phenolic compounds with antioxidant activity, such as ferulic acid, proanthocyanidins and lignans (Arendt and Zannini, 2013).

Despite having many advantages over wheat, the global triticale production is still scant, and the market value of

its grain is not as valuable as common wheat, owing to inferior flour quality that limits its use in food products. Although, the increasing demand for products made from alternative cereals and with health appeal, has favored the popularization of triticale (Naeem et al., 2002). Furthermore, the expansion of its application in products for human nutrition would increase the world food supply, particularly under drought, land degradation, and climate change scenarios (Darvey et al., 2000).

In order to intensify the application of triticale in foods, it is crucial to know the chemical composition and the functionality of its grain components, because the processing industries have specific demands for each developed product. Triticale processing quality and end-product characteristics are influenced by its kernel size, shape and texture; flour-milling potential; enzymatic activity and protein and polysaccharide composition (Peña, 2004). Warechowska et al. (2016) studied the effect of triticale kernel size on flour yield and concluded that smaller kernels had lower flour yield and higher ash content than larger

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kernels. According to Dennett and Trethowan (2013), the milling behavior of triticale is affected by kernel texture and tempering moisture. They observed that at lower tempering moisture, triticale presents higher flour yield and protein.

This study investigates the physicochemical composition of modern triticale genotypes and their milling behavior for food applications.

MATERIALS AND METHODS

Materials

Eight Brazilian triticale genotypes (BRS 203, BRS Harmonia, BRS Minotauro, BRS Saturno, BRS Ulisses, Embrapa 53, IPR Aimoré, and IPR 111), five advanced triticale lines (TLD 1103, TLD 1202, TLD 1203, ITW 11014, and TPOLO 0611) and two hexaploid wheat genotype references (IPR Catuara and LD 122105) were evaluated. Each sample consisted of 4kg of grains, originating from the same agronomic experiment, carried out in 2014 at the IAPAR experimental station, in Londrina city, Paraná. The materials were sown on the same date and grown under identical conditions: same soil type and same fertilization and irrigation conditions.

Grain analysis

Grain analysis included the test weight (TW) using AACC method 55-10.01 and percentage of sprouted grains, evaluated visually, in sub-samples of 100 grains. Wholemeal was utilized to determine moisture content (AACC method 44-15.02), crude protein (AACC method 46-11.02), ash (AACC method 08-01.01), lipid (AOAC method 2003.6) and starch, following methods 038/IV of Instituto Adolfo Lutz 038/IV (2008) and Lane-Eynon titration (1923). Falling number was determined according to method AACC 56-81.03 and sodium dodecyl sulfate (SDS) sedimentation test was performed as described by Dick and Quick (1983).

Milling

Milling was conducted using a Chopin experimental mill model CD1 (France), according to AACC method 26-70.01, with pre-tempering of the grains to 15.5% moisture, based on AACC method 26-10.02. The milling behavior was evaluated by total flour extraction yield (FY), break flour yield (BF), and reduction flour yield (RF).

Statistical analysis

The data were evaluated by analysis of variance (ANOVA), and the variables protein, ash, lipid, starch, TW, SDS sedimentation, FY, BF, and RF were used for a principal component analysis (PCA) of the triticale genotypes using Statistica 8.0.

RESULTS AND DISCUSSION

The TW of the triticale genotypes (Table 1) ranged from 70–78 kg/hl, with an average value of 74 kg/hl, which was lower than the value observed for Catuara wheat, but comparable to the LD 122125 wheat. Aprodu and Banu (2016) obtained the same result and documented that the TW of triticale was between wheat and rye. The wheat genotype IPR Catuara exhibited an excellent TW (over 78 kg/hl). For triticale genotypes BRS Ulisses and BRS Saturno, the TW was good (between 75–78 kg/hl), while the other triticale genotypes and wheat LD 122105 were satisfactory (between 70–75 kg/hl) (Birou *et al.*, 2010).

The TW has been the focus of triticale breeding programs because of its direct association with FY and grain energy content (Randhawa *et al.*, 2015). Initially, triticale was reported to have a lower TW than wheat, as a function of shriveled seeds (about 60 kg/hl), while modern triticale grains are plump and have a heavier TW, reaching 80 kg/hl under favorable environmental conditions (Mergoum *et al.*, 2004).

The SDS test results for triticales ranged from 3.78–5.71mL, i.e., lower than observed for wheat genotypes (17.50mL for IPR Catuara and 20.04mL for LD 122105). According to Pattison and Trethowan (2013), in wheat breeding programs, the SDS sedimentation test is used as a rapid and small-scale screening method, applied in early generations to provide an estimate of gluten strength and potential baking quality of wheat. Thus, the SDS sedimentation test values for triticale genotypes are too low for good bread-making quality, confirming the weak gluten quality of triticale described in the literature (Tohver *et al.*, 2005; Ereku and Köhn, 2006).

The wide ranging falling number of triticale genotypes (from 62.00 to 227.50s) was significantly lower than the wheat genotypes (323.00s for LD 122105 and 597.00s for IPR Catuara). The latter limits its food use, particularly for baking, due to the modifications that the α -amylase causes to the functional properties of starch (Ereku and Köhn, 2006; Dennett *et al.*, 2013). The variability in the falling number of triticale allows a selection of genotypes tolerant to preharvest sprouting and with enzymatic activity adequate for different products (Dennett *et al.*, 2013). In the last decade, progress in triticale breeding has promoted a reduction of α -amylase activity, being possible to find modern triticale genotypes with a falling number higher than 200.00s, as observed in this study for BRS Saturno (Tohver *et al.*, 2005).

The optimal falling number for bread wheat is between 180.00–260.00s. Over 300.00s is satisfactory, and below 160.00s, the falling number is unsatisfactory for bread

baking (Birou et al., 2010). In this context, only triticale BRS Saturno exhibited an optimal falling number for bread making. However, as observed for the SDS sedimentation test, this genotype had a low gluten quality and would need the incorporation of additives or be blended with wheat flour, for this purpose. The other triticales presented a minimal falling number and could be used as additives for correction of flours with a high falling number, as in the case of IPR Catuara. They could also be beneficial for the malting and elaboration of fermented beverages or in products that are not influenced by the enzymatic activity of flour, such as cookies, breakfast cereals, cereal bars, and extruded products (Marciniak et al., 2008).

Generally, for wheat grains, an association between the percentage of sprouted grains and falling number is observed, with a reduction of 7.26s per 1% germination (Giacomin et al., 2012). However, except genotype BRS Saturno, triticale exhibited a low falling number, regardless

of the percentage of visible sprouted grains. Dennett et al. (2013) reported that the falling number between triticale and wheat could not be compared because, within the same range of low α -amylase activity, the triticales presented a falling number around 50% lower than wheat. For these authors, other factors, such as the action of endogenous enzymes on non-starch polysaccharides and the presence of specific storage proteins, markedly influence the viscosity of the triticale flour suspension.

Table 2 presents the chemical composition of the triticale and wheat genotypes. The protein content of the triticales was lower than wheat and ranged from 12.34–14.76% (dry matter). Early triticales had a higher protein content than wheat. However, over the last few decades, the efforts of breeding to develop genotypes with higher yield and plump grain, has resulted in an increase of starch and conversely, a decrease in protein content. Modern triticale genotypes now have a protein level similar or lower than most wheat

Table 1: Physico-chemical properties of triticale and wheat genotypes

Genotype	Test weight (kg/hl)	SDS (mL)	Falling number (s)**	Sprouted grains (%)
Embrapa 53	73.40±1.56	4.82±0.25	81.50±0.71	17.00±4.94
BRS Saturno	78.00±2.83	5.05±0.06	227.50±4.95	ND
BRS Harmonia	70.00±2.56	5.36±0.00	63.00±1.41	ND
BRS 203	74.00±1.13	5.00±0.00	167.50±3.54	3.00±1.14
BRS Ulisses	75.00±0.14	5.00±0.00	70.00±0.00	2.00±2.82
IPR 111	70.60±3.11	5.00±0.00	63.00±0.00	6.00±7.07
IPR Aimoré	72.20±2.55	3.78±0.21	62.00±0.00	4.00±4.24
BRS Minotauro	74.00±0.28	4.86±0.19	65.50±0.71	1.00±0.00
TLD 1103	73.20±1.84	5.71±0.00	63.50±0.71	5.00±4.24
TLD 1202	74.40±0.57	4.14±0.20	70.50±0.71	2.00±0.00
TLD 1203	72.00±4.24	5.36±0.00	62.00±0.00	5.00±0.00
ITW 11014	74.00±0.71	4.00±0.00	62.00±0.00	4.00±1.41
TPOLO 0611	72.40±3.68	5.41±0.07	80.00±0.00	8.00±5.65
IPR Catuara	83.10±2.69	17.50±0.11	597.00±4.24	ND
LD 122105	73.80±0.85	20.04±0.17	323.00±5.66	2.00±0.00

ND: not detected, SDS: sodium dodecyl sulfate sedimentation test. *Values are means±standard deviation of two determinations. **Minimum value detectable is 62s

Table 2: Chemical composition (dry basis) of triticale and wheat grains

Genotype	Protein (g/kg)	Ash (g/kg)	Lipid (g/kg)	Starch (g/kg)
Embrapa 53	146.70±3.37	22.70±0.39	11.90±0.60	685.70±1.85
BRS Saturno	142.80±0.35	20.00±0.52	14.30±1.70	691.80±1.25
BRS Harmonia	123.40±3.73	21.20±0.12	16.70±2.50	700.60±1.92
BRS 203	128.80±1.20	21.70±0.25	13.00±0.39	719.20±2.10
BRS Ulisses	147.60±0.65	22.20±0.28	15.40±1.14	688.80±0.62
IPR 111	124.60±1.63	21.80±0.26	13.40±0.29	725.70±1.41
IPR Aimoré	133.00±0.99	21.60±0.25	14.20±0.33	699.10±0.65
BRS Minotauro	138.50±2.42	21.80±0.27	12.20±0.44	701.00±1.32
TLD 1103	130.80±0.79	20.90±0.20	13.30±0.63	712.70±0.68
TLD 1202	128.30±0.45	20.50±0.16	11.20±0.21	712.40±1.98
TLD 1203	130.90±2.54	21.20±0.23	11.10±0.10	698.40±0.65
ITW 11014	131.20±2.15	21.70±0.28	14.40±0.09	702.90±0.64
TPOLO 0611	136.80±1.35	20.90±0.18	12.90±0.19	697.30±1.93
IPR Catuara	152.50±3.00	18.60±0.19	11.70±0.22	692.10±0.62
LD 122105	170.60±2.81	18.40±0.31	18.50±0.79	666.60±1.16

*Values are means±standard deviation of two determinations

genotypes, when cultivated under the same conditions (Mc Govern et al., 2011).

Starch, the major grain constituent, varied from 68.88–72.57% for the triticale genotypes. Dennett et al. (2013) found that starch content in whole meal triticale is slightly lower than wheat, but in this study, the starch content was similar for the triticale and wheat IPR Catuara, while the wheat LD 122105 presented the lowest content (66.66%). Modern triticale breeding programs have focused on increasing the plumpness of grains, and consequently, the starch content has improved, a trait that is desirable for industrial applications, such as bioethanol or bioplastic production (Randhawa et al., 2015).

The ash content for triticales ranged from 2.00–2.27%, and was higher than the wheat genotypes (1.86% for IPR Catuara and 1.84% for LD 122125). Likewise, Pattison and Trethowan (2013) also verified that triticale exhibits a higher ash content than wheat in both the whole grain and flour. Although a high ash content (or total mineral content) is favorable for nutrition, it is associated with a low milling yield, poor baking quality, and a dark flour color, characteristics that limit the adoption of triticale in processed food products (Peña, 2004). Nonetheless, the increasing demand for products made from alternative cereals and with health appeal has favored the popularization and incorporation of triticale, particularly in wholemeal food products (Naeem et al., 2002).

The average lipid content of triticale grain was 1.34% and ranged between 1.11–1.67%. Lipids are predominant in the germ and are partially removed during the milling process. Despite the small fraction present in the grains, lipids have a significant influence on dough properties. At lower concentrations, lipids can decrease loaf volume, restricting the swelling of starch granules and reducing protein extractability. Conversely, higher concentrations stabilize the gas cells, promoting increased loaf volume (Goesaert et al., 2005).

The FY presented a considerable variability for the triticale genotypes, ranging from 55.73–63.36% (Table 3). These results were comparable to wheat LD 122105 (55.01%) and Catuara IPR (62.26%). Gil (2002) evaluated spring triticales and found similar extraction rates (54.50–62.20%) to those recorded in the current study. Early triticale genotypes had long grains, with a deep crease and incomplete plumpness that resulted in a lower FY than wheat. However, with the improvement of grain shape and plumpness, modern triticale genotypes have an FY equal or close to wheat (Peña, 2004). Observing the (Fig. 1), it can be verified that, in fact, the aim of tricale breeding programs has been achieved: although IPR Catuara wheat had more plump

Table 3: Yield of flour extraction, break flour and reduction flour

Genotype	Total flour yield (%)	Break flour yield (%)	Reduction flour yield (%)
Embrapa 53	60.27±3.42	13.49±1.73	77.93±2.90
BRS Saturno	63.36±2.70	14.13±0.40	79.68±4.36
BRS Harmonia	60.88±2.80	19.67±2.51	78.19±0.59
BRS 203	60.35±1.46	18.56±1.01	80.87±1.40
BRS Ulisses	57.24±2.66	13.47±1.88	75.70±0.62
IPR 111	60.71±1.26	17.50±2.25	80.95±1.37
IPR Aimoré	55.73±2.51	20.78±0.79	72.60±2.76
BRS Minotauro	57.90±1.49	13.88±1.19	75.01±1.10
TLD 1103	61.63±0.86	18.27±1.34	84.31±1.32
TLD 1202	62.55±2.00	18.77±0.05	79.80±1.32
TLD 1203	60.87±2.22	16.89±0.51	79.19±0.68
ITW 11014	62.82±1.27	15.14±1.14	81.28±0.85
TPOLO 0611	58.68±0.11	10.62±0.57	78.44±1.71
IPR Catuara	62.26±0.34	11.87±1.15	78.86±2.94
LD 122105	55.01±0.77	35.64±0.41	59.45±4.08

*Values are means±standard deviation of two determinations

grains, LD 122105 wheat and triticale genotypes presented similar grains shape.

The BF also displayed considerable variation for both, the triticales (from 10.62% for TPOLO 0611 to 20.78% for IPR Aimoré), as well as wheat genotypes (11.87% for IPR Catuara and 35.64% for LD 122105). According to Sevidanis et al. (2012), the manner in which the grain breaks and the behavior of the produced flour is an indicator of grain texture. Compared to hard grains, soft grains require less energy in the milling process, generate large amounts of BF with intact starch granules and have a lower water absorption, and hence, indicated for the production of cookies and cakes. In contrast, hard textured grains have a higher energy consumption, a reduced BF percentage, substantial amount of damaged starch and a high water absorption, ideal for bread (Martin et al., 2007). Thus, the texture of the IPR Catuara wheat grains can be considered hard due to the low BF, while, the LD 122125 wheat can be regarded as soft because its BF was relatively high. The variable BF of the triticales was due to differences in the grain hardness. In this study, the tempering and milling conditions were standardized, accentuating this variability. Dennett et al. (2013) suggested that the hardness of triticale grains should be assessed before milling, to adjust the tempering and milling conditions to this characteristic.

Regarding the RF, the highest percentage was observed for triticale TLD 1103 (84.31%), while wheat LD 122125 produced the lowest percentage (59.45%). In general, if the BF is high, the RF is low, because most of the flour has already been extracted in the breaking step, as was verified for the wheat genotypes. However, for triticales, this relationship was not observed, probably due to the standardization of milling and tempering conditions for



Fig 1. Wheat samples: (A) IRR Catuara; (B) LD122105. Triticale Samples; (C) TLD 1202; (D) TPOLO 0611; (E) ITW 11041; (F) BRS Minotauro; (G) IPR 111; (H) TLD 1103; (I) TLD 1203; (J) IPR Aimore; (K) BRS 203; (L) Embrapa 53; (M) BRS Saturno; (N) BRS Harmonia; (O) BRS Ulisses.

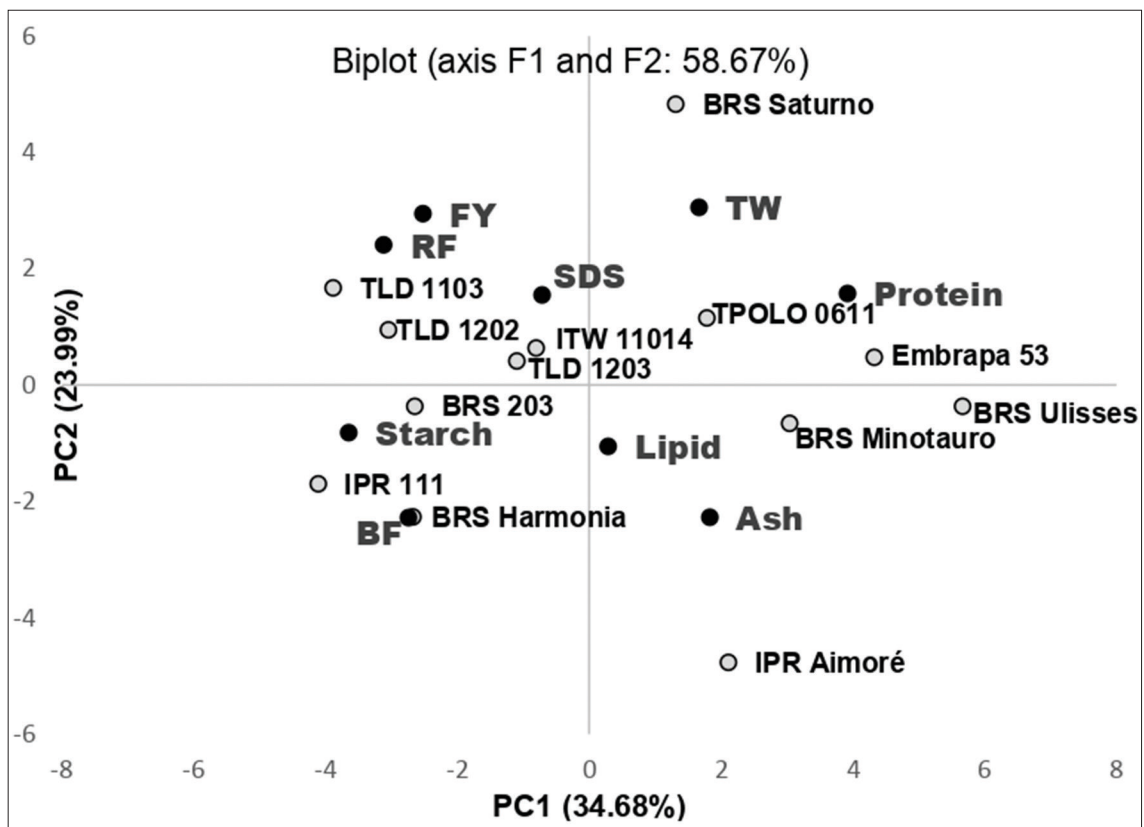


Fig 2. Principal component analysis of triticale genotypes (FY: flour extraction yield. TW: test weight, SDS: sodium dodecyl sulfate sedimentation test, RF: reduction flour yield, BF: Break flour yield).

grains with different textures, which did not allow an efficient extraction.

Although triticale is generally compared to soft texture wheat, the grain milling results showed that the behavior of studied genotypes was closer to hard texture wheat.

PCA was performed to evaluate the simultaneous influence of the main parameters studied in the triticale genotypes discrimination and to verify which components or set of constituents exerted a greater influence on the characterization of the same.

Together, the principal components (PC) 1 and 2 of the PCA explained 58.67% of the total variance (Fig. 2), with PC1 contributing 34.68% and PC2 accounting for 23.99%. PC1 correlated positively with the protein content and negatively with the parameters starch, BF, and RF. Thus, among the genotypes, those grouped on the right-hand side of the biplot, namely, BRS Saturno, Embrapa 53, BRS Ulisses, BRS Minotauro, and TPOLO 0611, presented a higher protein content, lower starch content and lower BF and RF, whereas those located on the left-hand side of the graph showed the inverse behavior.

PC2 was negatively correlated with the ash content and positively correlated with the FY and the TW. Thus, due to the highest TW, a higher FY, and a lower ash content, triticale BRS Saturno was segregated at the top of the biplot. The genotype IPR Aimoré also stood out from the others but was located on the bottom of the biplot, due to the lower FY. The main component analysis revealed that the variables that exerted the greatest influence on the characteristics of the triticale genotypes were protein, starch, ash, TW, BF, RF, and FY.

CONCLUSION

Falling number was not associated with the α -amylase activity for triticales, however, the variability observed would make it possible to develop genotypes with acceptable values for this parameter. A considerable variability in grain hardness also was observed for triticales, and its milling behavior was closer to the hard texture wheat. The studied triticales can be used in food products that do not require high gluten strength, such as cookies and cakes, or for products in which ash content or α -amylase activity are irrelevant, such as extruded cereals and cereal bars.

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Author's contributions

Érika Watanabe: designed, planned and executed the experiment, Klever Marcio Antunes Arruda: designed and planned the experiment; analyzing the results, Cintia Sorane Good Kitzberger: designed and executed the experiment; analyzing the results, Maria Brigida dos Santos Scholz: designed and planned the experiment; writing and analyzing the results, Alexandre Rodrigo Coelho: supervised the study; writing and analyzing the results. All the authors have read and approved the final manuscript.

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