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Triticale Flours: Composition, Properties and Utilization

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ABSTRACT

Triticale (X *Triticosecale* Wittmack) is an artificial hybrid of wheat (*Triticum* sp.) and rye (*Secale* sp.) first bred in laboratories during the late 19th century. In little more than a century, triticale has developed from a biological curiosity to a practical crop. Plant breeders have made efforts to overcome main problems of triticale: preharvest sprouting, susceptibility to diseases, sensitivity to photoperiod, and production of shriveled grains. Triticale world production is in constant growth, in 2005 15,000,000 t were produced all over the world. Today, it is used as forage or grain. The chemical composition of triticale has similarities with wheat and rye, showing intermediate values in many of the parameters. Due to presence of rye proteins, triticale flours have low gluten content, deficient gluten viscoelasticity, and, consequently, produce breads with inferior quality than wheat. However, triticale is still an alternative for human food, essentially in areas where soil and climate conditions limit wheat growth. In Latin America triticale performs well in southern semi-arid regions and in Brazilian acid soils. In some parts of eastern and northern Europe where wholemeal flours are used today for breadmaking, triticale breeding is increasing progressively. In this article we approach the aspects linked with the utilization of triticale flours for human consumption.

Keywords: breadmaking, cookie, cracker, gluten, protein, starch

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INTRODUCTION

Triticale (X *Triticosecale* Wittmack) is a hybrid produced by crossing wheat (*Triticum* sp.) with rye (*Secale* sp.). Wilson (1876) obtained the first two plants through manual pollination of emasculated wheat flowers with rye sterile pollen; they resulted in sterile plants. Several years passed until the first fertile triticale was reported (Rimpau 1891).

Little more than a century later, triticale went from being a mere biological curiosity to being a commercial crop. The finding of colchicine action as an inductor of chromosomal duplication (Skovmand *et al.* 1984), as well as the improvement of embryo culture techniques (O'Mara 1948) gave it an important impulse.

The first scientific publications on triticale came from Europe (primarily Austria, England, Germany, the Netherlands, Hungary, Italy, Russia, Spain, and Sweden); while in the middle of the 20th century the first publications from Canada, the United States, and Japan appeared (Lorenz 1974).

In the Americas, the first research program was established in 1954 at the University of Manitoba, Winnipeg, Canada and in 1964 a triticale development program was created at the International Maize and Wheat Improvement Center (CIMMYT) located in México (Lorenz 1974).

Origin of the name

Tschermak and Bleier (1926) suggested the name "Aegilo-

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cale" to designate an *Aegilops* X *Secale* hybrid and "Aegilotricale" for a hybrid that combined the genera *Aegilops*, *Triticum,* and *Secale*. Leighty and Sando (1927) gave this hybrid the name of "Aegilotriticale" to indicate more clearly the presence of the genus *Triticum*. The name "Triticale" was proposed by Tschermak (1938) for the *Triticum* X *Secale* hybrid which had wheat as mother and rye as father; for reciprocal crossing he proposed the name "Secalotricum".

Thirty years later, the name "hexaploid triticale" was suggested to designate hybrids formed by 42 chromosomes and "octaploid triticale" for those formed by 56 chromosomes (Larter *et al*. 1968). In 1971 Baum suggested the generic Latin name of *Triticosecale* Wittmack (Royo 1992).

Table 1 Major triticale producers of the world (t) in recent years.

	1995	2000	2005
Poland	2,048,148	1,900,959	3,903,000
Germany	1,643,200	2,799,805	2,675,900
France	843,100	1,261,640	1,809,386
Belarus	113,000	311,000	1,121,496
Australia	468,513	841,000	675,000
Hungary	219,000	235,592	567,738
China	95,700	365,040	559,000
Czech Republic	63,786	138,468	255,186
Sweden	223,900	185,100	271,500
Lithuania	46,600	130,900	201,100

Data from FAO 2006.

Types of triticale

As a result of numerous crossings, amphidiploid organisms were obtained from various genomic structure and degree of polyploidy. Kiss (1966) introduced the term "primary triticale" to designate the allopolyploids obtained from wheat and rye. The genotypes obtained from the crossing between primary triticales or from the crossing of primary triticale with wheat or rye were called "secondary triticale", regardless of the degree of polyploidy.

Primary octoploid triticales (2n= 8x= 56; AABBRRDD) were obtained using *T. aestivum* (hexaploid) as female parental, while hexaploid hybrids (2n = 6x = 42; AABBRR) were produced by crossing *T. dicoccoides* or *T. durum* (tetraploid) with *Secale* sp. (diploid).

The significance of this interspecific hybrid lay in the combination of the good characteristics of both parents such as wheat's high productivity, short stature, and good bread-making quality with rye's resistance to diseases, adaptability to acid soils and robustness (Oettler 2005). However, expected results were not obtained because primary triticales did not show the desired characteristics. Subsequent studies revealed that the interaction between wheat and rye genomes influences the phenotypical expression of characters in primary triticales (Lelley 1992). Therefore, parental line quality traits and performance have a limited predictive value for the new amphidiploid performance. Besides, primary triticales have cytological instability, low fertility and poor agronomic performance.

The first secondary triticales were produced by crossing primary octoploid triticales (Katterman 1936; Muntzing 1939); however octoploid triticales revert to hexaploids. Triticale commercial growth was achieved with the development of secondary hexaploid triticales, which is nowadays the triticale type widespread around the world, except for China where secondary octoploid triticales are cultivated for their quality in steam bread production (Bao and Yan 1993).

Geographic distribution

Triticale world production is in constant growth. The first records indicate that in 1975 1,200 t were produced all over the world and around 15,000,000 t in 2005. Triticale is cultivated in most parts of the world; the 10 major producers are detailed in **Table 1**.

There has been a rapid increase in triticale production in several European countries, such that in 2005 triticale production was among the 20 most important crops in such countries as Poland, Germany, France, Belarus, the Czech Republic, Sweden and Lithuania (FAO 2006). Over the same period, a remarkable increase in Triticale production occurred in Chine (**Table 1**).

Agronomic traits

Morphologically, the triticale plant bears general similarities with wheat; triticale plants are on the whole more robust, more vigorous, and have larger spikes (Bushuk and Larter 1980). Depending on the plant genetic constitution, climatic conditions, and on crop technology, various types of seeds are obtained that may go from partially shriveled to plumper seeds. Plant breeders have made efforts to overcome preharvest sprouting, as well as susceptibility to diseases, sensitivity to photoperiod, and production of shriveled grains. In any case, cultivation conditions are factors of high importance in the determination of grain quality, especially solar radiation and nitrogen contribution. Preanthesis shading produced a significant decrease on triticale yield and shading after anthesis produced a decrease on test weight, while N fertilization in triticale favored the formation of protein aggregates of high molecular weight and increased the ratio of polymeric to monomeric proteins (Aguirre *et al*. 2006).

The first efforts to improve grain were directed to avoiding shriveling. Grain shrivelling is an undesirable characteristic that results in low grain test weights and low flour yields (Peña and Bate 1982; Peña and Amaya 1992). This disadvantage is originated, after cell division, when proteins and starch are deposited in the endosperm which forms a starch protein matrix (Jönsson 1987). After 20 years of intensive selection, the shriveled grain is not a central problem any longer (Darvey 2006).

Another problem with triticale is its tendency to preharvest sprouting, specially humid weather conditions. This susceptibility, inherited from rye, is strongly link to α-amylase activity in the seed and is normally determined with the Hagberg Falling Number test. High levels of α-amylase not only imply sprouting problems in the spike, but also a deterioration of the industrial quality, since a high enzymatic activity produces problems during baking (doughs are sticky and badly machinable, bread volume is low, and crumb has little flexibility) (Edwards *et al*. 1989). This phenomenon worsens in rainy years because there is a higher effect of rainfall during the whole growing season of the crop and between anthesis and harvest (Aguirre *et al.* 1993). In spite of the efforts, high α-amylase activities and consequently low Falling Number values continue to be a significant problem in new triticale cultivars (Martinek *et al*. 2008).

Triticale has proved to have a great adaptation capacity to acid and saline soils (Liu *et al*. 2004; Morant-Manceau *et al*. 2004), and also potentiality in the Mediterranean environment (Santiveri *et al.* 2002). Considering other uses (for example as forage), the effect of sowing rate and intercepted radiation on the capacity to produce dry matter per unit area should be stressed (Giunta and Motzo 2004).

GRAIN CHARACTERISTICS

Structure

Triticale grains are yellowish brown in color; their external morphology is similar to wheat and rye. The shriveled grain has been the main quality defect in many triticale cultivars, resulting in a smaller hectoliter weight and in a low milling yield. Many of the new triticale cultivars do not have this problem but invagination is more depressed than wheat grains. **Fig. 1** showed cross sectioned grain from wheat and triticale.

Fig. 1 Cross section of wheat (left) and triticale (right) kernels.

Table 2 Chemical composition of the grain from 20 triticale cultivars grown in Argentina.

	Moisture (%)	Protein (%)	Lipids (%)	Carbohydrate (%)	Ash (%)
Triticale	10.5	13.0	2.1	72.1	2.2
Wheat	11.6	12.0	1.7	72.9	1.6
Rye	10.9	14.8	2.5	69.8	2.0

Adapted from USDA Nutrient Database
http://www.nal.usda.gov/fnic/foodcomp/search/

Composition

Triticale grain chemical composition bears similarities with wheat and rye, having intermediate values in many of the parameters (**Table 2**).

The first studies on chemical composition were performed with triticale grains of very poor quality, and they showed higher levels of protein content than wheat grains; further improvements in grain filling have made protein content go down and put triticale grain at similar level of wheat. Grain filling increase implies an increase of the starch deposit in the endosperm, reducing protein concentration.

Nutritional value

The most important nutritional factors in the triticale grain are starch content and protein amount and quality. Numerous works compare nutritional value of triticale and wheat. The influence of genotype, crop growth conditions and experimental treatments on nutritional value do not allow a generalized summary. However, there is an agreement that triticale has higher or similar protein concentration and protein efficiency ratio (Hill 1991; Kulshrestha and Usha 1992). Generally, triticale had shown higher amount of lysine than wheat (Villegas *et al.* 1970; Varughese *et al.* 1996a). However, the high lysine levels of the early triticales could have been due to the high protein contents of those shriveled grains; amino acid composition of new triticale lines is very similar to wheat (http://www.nal.usda.gov/fnic/foodcomp/search/).

Villegas *et al.* (1980) studied the protein quality in rats, they found that the digestibility of triticale proteins is similar to wheat, while the biological value and protein use is 10% higher. Like in wheat, lysine is the limiting amino acid in triticale. Studies performed with rats established the following sequence of limiting amino acids: lysine, threonine, methionine, and valine (Heger 1990).

In one of the few studies performed with human beings, young adults were fed with yeast-raised rolls made from the wheat or triticale whole meal. At a protein intake level of 4 g N/day, Body nitrogen loss was -0.62 g N/day for wheat and -0.44 g N/day for triticale (Kies and Fox 1970a). They concluded that the biological value of triticale was superior to wheat, and it was advisable to supplement it with lysine (Kies and Fox 1970b).

Lorenz (1974) analyzed some articles which studied the nutritional quality of triticale using different animal system. In general, triticale showed better results than other cereals in cattle, sheep, swine, turkey, chicken and rat. However, in chickens the high pentosan content of triticale may create a viscous environment within the intestinal lumen (Smits and Annison 1996). Increased viscosity is associated with lower apparent metabolisable energy (Austin *et al.* 1999) as well as nutrient absorption and incidence of wet and sticky droppings (Smits and Annison 1996).

Triticale contains potassium, calcium, phosphorus, and manganese in higher proportions than wheat; what's more, it shows large quantities of iron, sodium, and zinc (Lorenz 1974).

Triticale vitamin content is richer than wheat in biotin, folic acid, and vitamin B6, and lower in thiamine, riboflavin, and pantothenic acid (Michela and Lorenz 1976). It is well known that dietary fibre plays an important role in many physiological processes and in the prevention of diseases of different origin. In spite of crude fiber content of new triticales is similar or lower than wheat and rye levels (Picolli da Silva and Santorio Ciocca 2005; Józefiaka *et al.* 2007) the total dietary fibre level was higher than wheat due to the high trticale arabinoxilan and β glucans content (Cyran *et al.* 1996; Józefiaka *et al.* 2007).

FLOUR PRODUCTION

Triticale milling yield is lower than wheat, both in experimental Buhler mill (Unrau and Jenkins 1964; Kaltsikes and Larter 1970), and in Quadrumat Senior mill (Lorenz 1972; Madl and Tsen 1974). Lower milling yield is mainly due to the elongated shape of the grain, to the higher relation between external surface and volume, and to the excessively soft endosperm.

Lightness (L*, CIELAB) measured on 10 wheat and 10 triticale flours were L = 93.51 ± 0.27 and L = 91.95 ± 0.26, respectively (results not published). The color of triticale flours – slightly darker than wheat flours – is one of the main hindrances to be use in bakery.

In the endosperm, starch granules are found in a protein matrix. During milling, a fraction of starch granules is damaged, thus causing what is called damaged starch. The degree of the damage depends on severity of grinding and on grain hardness. Damaged starch affects flour properties; it mainly modifies its hydration capacity, since damaged starch absorbs 3 times more water than the starch found in intact granules (Bushuk 1998). The increase in the water absorption capacity has a negative effect on cookie production because water evaporation during cooking is an important point in the production process. In leavened products, the dough loses consistency and stickiness increases. Damaged starch granules are very susceptible to the attack of the amylases common in flour, which produces a modification of yeast activity during dough preparation. Barrera *et al.* (2007) reported that damaged starch levels greater than 10% produced deleterious effects of both bread and cookie quality.

Composition and functional properties

As result of the milling process non-whole flours have different chemical composition than grains. Increasing the extraction rate causes more aluerone/bran to appear in the flour so both the ash and the protein contents increase at the expense of starch content. A comparison between compositions of flours at different extraction rates is shown in **Table 3**. According to different studies, protein content in triticale may decrease between 15% and 28% (Peña 1979; Germany *et al.* 1991); if it is analyzed considering grain hardness, a decrease of 26.9% is observed in soft triticales, 14.5% in semi-hard, and 9.6% in hard ones (Amaya *et al.* 1986).

Along with ash and protein contents increase, starch content decreases without causing significant modifications in the rest of components.

Flour functional properties are mainly determined by gluten and the role it has in endowing the dough with strength and elasticity during the kneading and cooking process of baking products. Generally, triticale flours produce

Table 3 Variations in starch, protein, and ash concentrations at different extraction rates.

	Extraction rate of flour		
	100%	**80%**	**70%**
Starch	60.2 ± 3.4	66.4 ± 3.0	74.6 ± 3.4
Protein	12.9 ± 0.9	11.4 ± 0.7	10.8 ± 1.3
Ash	1.4 ± 0.2	0.9 ± 0.3	0.6 ± 0.1

Ash and protein contents were determined according to the approved AACC methods 08-01 and 46-10, respectively. Moisture (44-01) and crud fat (30-20) were measured in order to obtained starch values by difference (AACC 2000)

weaker doughs with different rheological properties from wheat. Triticale has higher enzymatic activity (Aguirre *et al.* 1995, 1996), protein content, and water-soluble protein content than wheat (León *et al.* 1996). Higher water-soluble protein content implies a smaller proportion of gluten proteins and a poorer performance in breadmaking. Besides, the genome of triticale contains the chromosomes of rye, the secalins encoded by rye chromosomes have a negative influence on the bread quality of triticale. The presence of the 1RS segment in triticale is responsible for significant reduction in rheological properties and overall gluten strength, and significant increase in dough stickiness (Peña and Amaya 1992)

In wheat there is a strong correlation between flour protein content and gluten content. This correlation is much smaller in triticale because part of its proteins comes from rye and has less ability to form gluten (Skovmand *et al.* 1984). Likewise, there are lines of triticale that produce a gluten content similar to the best bread-wheats, which does not entail a good performance in baking (CIMMYT 1980). Probably, the high α-amylase activity and secalins from rye become the limiting factors to obtain good bread with triticale (Varughese *et al.* 1996b).

Proteins

In wheat and other cereals, including triticale, protein metabolism is a complex process that involves a series of enzymatic stages. Nitrogen is taken by plants as nitrate. Nitrate is reduced to ammonium by nitrate and nitrite reductases, in a two-stage process in which nitrite reductase is the first limiting enzyme in the protein synthesis (Hageman *et al.* 1976). The incorporation of ammonium to free amino acids implies the action of glutamine synthase and glutamate synthase (Huffaker and Rains 1978). Many other enzymes contribute to the incorporation of amino acids to proteins, to the hydrolysis of these proteins, to nitrogen translocation to the developing grain, and lastly, to the seed storage protein synthesis.

Wheat grain proteins can be divided in two large groups: gluten and non gluten proteins. The average content of triticale wet gluten ranges between 24% and 25%, significantly lower than in wheat (Aguirre *et al.* 2002).

In triticale, the albumin and globulin fraction synthesis is produced at the beginning of the grain filling stage, while with time, the speed of prolamin and glutelin synthesis (**Fig. 2**) increases. Concomitantly, a greater proportion of high molecular weight proteins are observed as the grain approaches maturity (Pérez *et al.* 2004).

Triticale proteins contain 27.9% of prolamins and 32.3% of glutelins; glutelin concentration goes up with the increase of flour protein concentration, while prolamin concentration goes down. The molecular weight of prolamin group proteins is between 25,000 and 70,000. Triticale glutelin molecular weights are between 22,000 and 100,000. Triticale flours have sulfhydryl group content similar to wheat, between 0.87 μM/g and 2.16 μM/g (León *et al.* 1996).

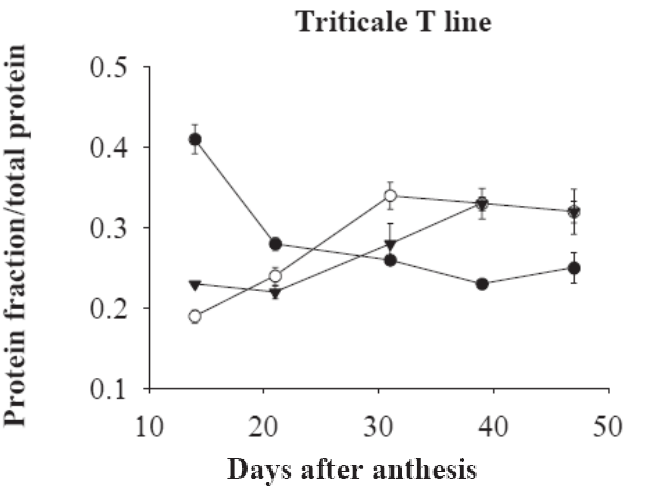

Fig. 2 Changes in albumin-globulin (●), prolamin (○) and glutelin (▼) proportions in total proteins from developing grains of triticale (Reproduced with permission from Pérez *et al.* 2004). Error bars are standard deviation.

Starch

Cereal grains store energy in the form of starch, which occupies between 60% and 75% of the grain weight. Starch is generally found as granules, which allow it to compact itself densely and to be insoluble in water, while it remains inaccessible to enzymatic action, before germination.

In cereals, starch is stored in two types of granules ranging in size between 2 and 10 μm for B type, and 15 and 35 μm for A type (**Fig. 3**). In triticale, granules also show a bipolar distribution; the A type are between 15 and 20 μm in diameter and the B type around 5 μm. At the beginning of the grain filling stage, bigger granules predominate, but the proportion of B type granules increases as maturity gets closer (Pérez *et al.* 2004).

Starch is a cold-water insoluble macromolecule made of two fractions: amylose, a lineal molecule made of α-D-glucopyranose units linked by α-(1-4) glycosidic bonds, although it has been established that some molecules branch out through α-(1-6) bonds (Buleón *et al* 1998). Amylopectin, on the contrary, is a highly branched polymer with molecular weight higher than 10^8. The main chain is made up of α-D-glucopyranose units linked by α-(1-4) bonds and chained to hundreds of small chains through α-(1-6) bonds at the ramification points. In triticale, it has been observed that starch is formed by smaller or less branched chains than wheat (León *et al.* 1998).

Because the internal part of the granule consists of alternating crystalline and amorphous regions, starch is described as a semi crystalline or partially crystalline polymer (Eliasson and Gudmundsson 1996). The study of crystallinity by X-ray diffraction reveals that the various types of starch produce three kinds of patterns, called A, B, or C. Triticales give an A pattern, like most cereals (León *et al.* 1998).

When the water-starch system is heated, water penetrates in the amorphous regions and the granule starts to swell; starch from the surface of the arranged crystals takes water and breaks them. This process is known as gelatinization and it involves (Donovan 1977): a) starch hydration

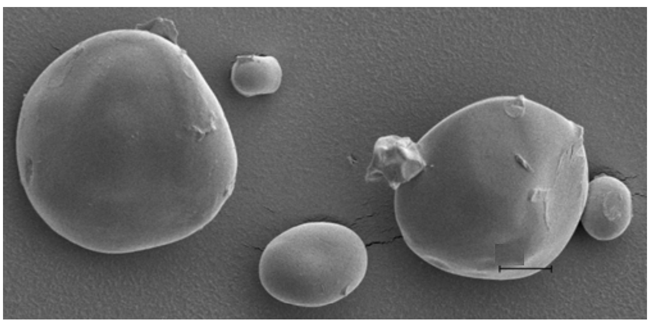

Fig. 3 Microphotography from triticale starch granules. Bar = 5 μm.

with swelling of granules and reduction of relaxation time of water molecules; b) granule structure disruption; c) heat absorption; d) grain crystallinity loss.

If water/starch relation is low, the remaining crystals are melted at a higher temperature giving way to the second endothermic transition (Larsson and Eliasson 1991). If the area included in the endotherm is integrated, the transformation ΔH can be calculated.

Gelatinization temperature and ΔH maintain a greater dependence on water content. In the case of wheat starch, adding water up about 70% of moisture, gelatinization temperatures between 60°C and 62°C have been reported (Ghiasi *et al.* 1982; Zamponi *et al.* 1990). Peak temperatures between 58°C and 62°C and ΔH between 4.1 and 6.6 J/g have been reported in ten triticale flour samples with similar moisture contents (León *et al.* 1998).

Starch transformation in an amorphous material is a process that may be reverted with time. This process is globally known as retrogradation and it takes place in two steps kinetically different a) a fast amylose gelation through the formation of segments of chain in double helix, followed by a helix-helix aggregation, and b) a slow recrystallization of short amylopectin chains (León *et al.* 1997).

The role of starch in the preparation of baking products has received lesser attention than the one accorded to gluten-forming proteins mainly because its properties are not affected much by the differences in cultivation conditions or by varietal diversity (D'Appolonia *et al.* 1971). In any case, for a long time it has been known that starch fulfills the following functions in breadmaking (Sandstedt 1961): 1. It dilutes gluten giving a desirable consistency, 2. It provides sugar for fermentations, 3. It provides a suitable surface for gluten to adhere strongly, 4. It cooperates in the retention of the gas formed, and 5. It absorbs water from gluten during gelatinization to fix the gluten film that under these conditions becomes rigid and permeable enough to gas as to avoid dough collapse during cooling.

As was previously stated, starch play an important role in bread staling; bread firming and amylopectin retrogradation in triticale are similar to wheat (León *et al*. 2006). Increase of damaged starch content affects cookie and bread quality (Barrera *et al*. 2007) and increases both amylopectin retrogradation and firming rate (León *et al*. 2006).

Lipids

The significance of lipids in cereal flours is clearly seen in the big changes in bread volume and texture produced when lipid content is altered. Polar lipids have shown favorable influence in baking, but the nonpolar lipids has detrimental effects. The function of lipids in baking can be linked to their effects on the formation and stability of the cell structure of dough (MacRitchie 1981).

Lipids may be divided in two large groups: polar and nonpolar. The latter, formed by triglycerides, are stored in spheresomes in the germ, the aleurone and the endosperm. Polar lipids are of two kinds: glycolipids and phospholipids; digalactosyldiglycerides and monogalactosyldiglycerides are glycolipids most important components, while phosphatidylcholine (lecithin) is the main one among phospholipids (Lindahl 1990).

Glycolipids are located in the amyloplast membranes of the starchy endosperm; phosphatidilcholine is located in small quantities in most mature grain membranes (Morrison 1989). Triticale contained several times more phosphatidylcholine and phosphatidylethanolamine than wheat and rye (Zeringue and Feuge1 1981).

PROCESSING AND USES

Triticale is used in the world as a forage crop or as grain. In this work we deal with the issues related to the use of the grain flour production for human consumption.

Triticale flours have proved to be more suitable for baking products that need poor gluten strength, while they have showed poor results in breadmaking. However, although they are an exception, some triticales from CIMMYT have an acceptable bread-making quality (Amaya *et al.* 1986).

For several years, studies have informed about the use of triticale flour in the production of bakery products such as cookies (Tsen 1974), cakes (Peña and Amaya 1980), tortillas (Serna-Saldívar *et al.* 2004), waffles and pancakes (Rodgers 1973). Among these products, important results about factors affecting production of cookies (León *et al.* 1996; Rubiolo *et al.* 1998; Ramírez *et al.* 2003; Roccia *et al*. 2006) and crackers (Pérez *et al.* 2003) were obtained. Even a book has been edited with more than 150 recipes to prepare leavened and unleavened breads, sponge cake, cookies, crackers and muffins, using triticale flour (Cooper 1985).

Breadmaking

Due to presence of rye proteins, triticale flours have low gluten content, deficient gluten viscoelasticity, and, consequently, produce breads with inferior quality than wheat. For many years, promising results have been obtained in the production of breads with wheat and triticale flour blends. With some triticale cultivars selected at the CIMMYT, good quality breads have been obtained with mixtures of equals parts of wheat and triticale flours (Peña and Amaya 1992).

Even though triticale flours can reach protein values similar to wheat, protein quality is lower because the glutelin/protein total relation is smaller than wheat. This is evidenced in low wet gluten values (Amaya and Peña 1991), or in the impossibility of some cultivars to form gluten (Thover *et al*. 2005). In these cultivars, proteins behave as rye proteins, which are not able to form gluten due to their structure, the high pentosan content, and the high α-amylase activity (Weipert 1996). Quality tests for baking flours such as SDS-SI and Zeleny yield inferior values than wheat.

The viscoelastic properties of doughs elaborated with triticale depend on the allelic composition of high molecular weight glutelins in the A and B genomes (Tohver *et al.* 2005). The baking quality needs the presence of genome D glutenin subunits of high molecular weight that are absent in triticale cultivars. Because of this, triticale has been mixed with wheat flour for baking.

Triticale flour added to wheat flour in 10% produced a larger specific loaf volume than bread from wheat flour (Doxastakis *et al.* 2002). In another work, good quality breads were obtained with a mixture of equal parts of wheat and triticale flours, with results that were highly cultivar dependent (Naeem *et al.* 2002). In a later study they managed to incorporate up to 70% of triticale flour keeping the quality of breads produced; the best results were obtained with lines that presented glutenin subunits of high molecular weight (2* and 7+26 and 7+19) (Tohver *et al.* 2005).

Recently, triticale lines with high molecular weight glutenins of D1-genome (subunits 5+10) were obtained from the translocation of wheat 1D-chromosome to 1R. This translocation increased the values of the Zeleny sedimentation index, reduced dough stickiness, but falling number values dropped, which revealed an increment in the amylase activity that would affect bread quality negatively. These new lines did not produce a significant increment of bread volume, although the form ratio (height/width) did improve (Martinek *et al.* 2008). This demonstrates that the absence of high molecular weight glutenins from D-genome does not fully explain triticale poor performance in baking.

Use of triticale flour for crackers and cookies

In general, good quality cookies are those that have high diameter, low height and a tender bite. At an experimental level, triticale flours that produce best cookies show low protein content, high prolamin percentage, low glutelin percentage, high proportion of prolamins of the 34,000 molecular weight protein group, low proportion of glutelins of low molecular weight proteins, and low sulfhydryl group contents (León *et al.* 1996).

Also, the quality of triticale flours to elaborate crackers was evaluated and it was found that various lines produced flours of very good quality to elaborate crackers. It was observed that crackers obtained from five triticale flours were similar to the crackers produced from optimum quality control flour. Besides, when the protein fractions were studied by electrophoresis, these five triticale flours showed a protein band of an approximate molecular weight 110kDa (Pérez *et al.* 2003).

Other factors that affect triticale flour quality to produce cookies are pentosan (Roccia *et al.* 2006) and damaged starch (Torri *et al.* 2003) contents. This is because the various flour components have different capacities to absorb water. One gram of protein absorbs between 1 and 3 g water, 1 g starch 0.4 g water, 1 g damaged starch between 1.5 and 2 g and the pentosans around 10 g water per gram of substance (Bloksma and Bushuk 1988).

Among other flour components, flour lipids increase cookie diameter (León *et al*. 2000), while ash affects cookie color (Ribotta *et al*. 2002).

In order to predict flour quality numerous physicochemical tests are used, such as SDS sedimentation index, alkaline water retention capacity, and in recent years, solvent retention capacity profile (AACC 2000). Recently, theses tests have been used successfully to predict the quality of triticale flours (Roccia *et al.* 2006).

In previous research, the authors carried out studies to select a triticale line to produce good quality cookie. After laboratory pre-selection analysis, cookies and wafers were produced in an industrial plant and the results compared with the products obtained from conventional flour mixture (wheat flour plus additives). A mixture of triticale flour and wheat flour (70:30 respectively) produced cookies with the same quality that cookies obtained with conventional flour mixture. Concerning wafer production, 100% substitution of wheat flour mixture by triticale flour produced “undistinguishable” wafer quality from the control (León 2007).

Other non leavened products: tortillas, pancakes, sponge cake

Triticale flours are also promising for non leavened products because they do not need a strong and elastic gluten network that may hold gases.

Layer cakes with good symmetry and uniformity have been obtained substituting 40% standard wheat flour for triticale flour (Tsen 1974). Sponge cakes produced with 50% triticale flour with emulsifiers in the formulation had greater volume than wheat flour ones (Kissell and Lorenz 1976). This product has also been produced with 100% triticale flour from various cultivars not showing significant differences in terms of volume, symmetry, and color from sponge cakes obtained in the same assay with soft wheats (Oliete *et al*. 2008).

Tortillas are original products from Mexico which carry flour, margarine, chemical leavener, and water in their formulation. Tortillas produced with 25% and 50% triticale were lighter and more flexible, and had greater acceptance for panelists than the controls produced with 100% wheat. Tortillas production with 100% triticale requires the addition of vital gluten to the formulation in order to avoid collapse during hot pressing (Serna Saldívar *et al.* 2004).

CONCLUSION

Triticale continues to be an alternative to human food, mainly in those parts of the world where diseases or adverse soil and weather conditions limit wheat growth. In Latin America triticale performs well in southern semi-arid regions and in Brazilian acid soils. In some parts of eastern and northern Europe where wholemeal flours are used today for breadmaking, triticale breeding is increasing progressively. At the same time, as more information is gained on triticale uses in the elaboration of products that require poor strength flours, the prospects of the use of triticale flours in the production of good quality cookies, crackers, and cakes without additives are significant.

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