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Review

Triticale: Nutritional composition and food uses

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ABSTRACT

Triticale (× *Triticosecale* Wittmack), a man-made cereal from wheat and rye hybridization, is mainly used as animal feed. In recent years, there has been increasing interest in utilising triticale for food production. Some chemical constituents (e.g., starch and non-starch polysaccharides) of triticale as well as the genetic variability in nutritional composition have been much studied. Various food and beverage products of triticale have been developed, including bakery products (e.g., bread and cookie), pasta, malt, spirit, yoghurt, and biodegradable and edible films. Focusing on the literatures from the last 5 years, this mini-review summarises the recent advances in the nutritional composition and diverse food uses of triticale. There is a wide variation in the chemical composition of triticale, which suggests the potential of triticale as a cereal alternative for various food and beverage applications.

1. Introduction

In 1875, triticale (× *Triticosecale* Wittmack) was developed by crossing rye (male parent) and wheat (female parent) (McGoverin et al., 2011). The original idea was to combine the positive quality attributes of both rye (tolerance to harsh growing conditions) and wheat (versatile food applications). The world production of triticale has kept growing during the last two decades, reaching ~17 million tonnes in 2014 (Fig. 1) (FAOSTAT, 2017). The top producers are Poland, Germany, Belarus, France and Russia. China is a major producer outside Europe (FAOSTAT, 2017).

Overall, the chemical composition of triticale appears to be more similar to wheat than rye. Some triticale genotypes have a relatively high concentration of lysine, which is the limiting amino acid of cereals (McGoverin et al., 2011). Nutrients of triticale that are gaining research focus include starch, non-starch polysaccharides (e.g., arabinoxylans), polyphenols (e.g., phenolic acids), alkylresorcinols, and vitamins (e.g., vitamin B1) (Buchholz, Drotleff, & Ternes, 2012; Rakha, Åman, & Andersson, 2013). Some health effects of triticale such as *in vitro* antioxidant and anticholinesterase activities were reported (Senol, Kan, Coksari, & Orhan, 2012). Therefore, triticale may play a role in the rising healthy food market and in the formulation of new cereal products. It should be noted that triticale contains gluten and is not suitable for people with celiac disease.

Triticale has been mostly used as animal feed (poultry, pigs, and ruminants). Interests in utilizing triticale for food and biofuel production were reported (McGoverin et al., 2011). Triticale by itself appeared to be unsuitable for bread but cookie production. Triticale-wheat composite flour is used for bread formulation (McGoverin et al., 2011). During the last few years, the range of chemical composition of triticale has been expanded through assessing more genetic resources (Manley et al., 2013). Recently, various triticale-based food products, such as bread and pasta, have been formulated in the laboratories (Navarro-Contreras et al., 2014). The wide range of composition may provide a solid basis to develop a variety of triticale based food products.

A previous review summarised the reports of triticale research up to the year of 2010 (McGoverin et al., 2011). The reviewed topics included triticale production, chemical composition, food, feed, and biofuel uses, and effects of growing environment on the production and composition (McGoverin et al., 2011). In recent years, more genotypes of triticale have been analysed for nutritional composition. Some specific components such as starch and cell wall polysaccharides have been studied in detail. Various food products of triticale such as edible films have been developed. This mini-review summarises the recent advances in the nutritional composition and food uses of triticale, providing a scientific basis to better develop triticale as a sustainable crop.

2. Nutritional composition of triticale grain

The nutritional composition of whole grain triticale flour (1 variety) is listed in Table 1 and has been reviewed previously by McGoverin et al. (2011). Recent studies continued to assess more genetic resource of triticale, while reporting a wider variation in the nutritional composition as described in the following sections.

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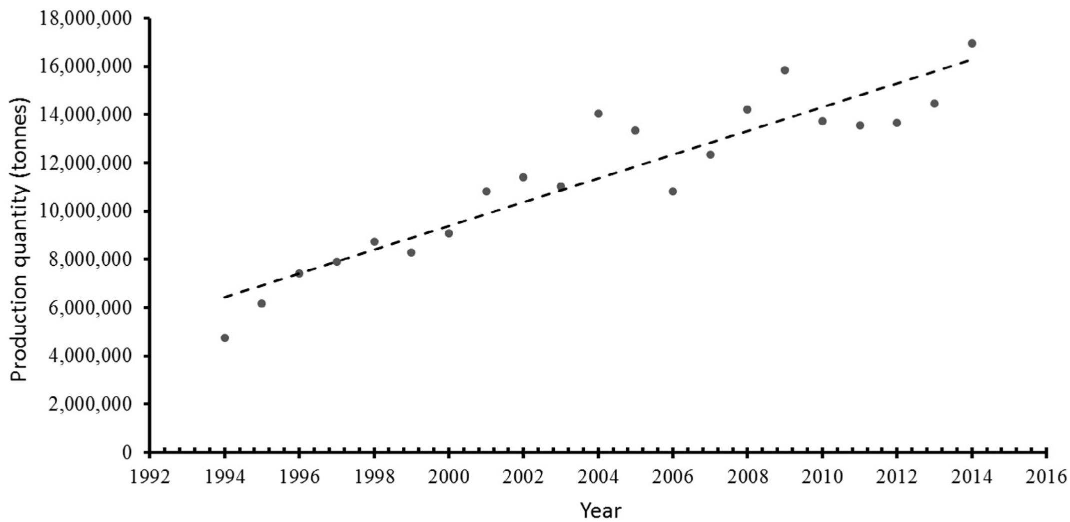

Fig. 1. World production quantity of triticale from 1994 to 2014; dashed line represents the general production trend; data may include official, semi-official, estimated or calculated data (FAOSTAT, 2017).

Table 1
Nutritional composition of whole grain triticale flour (1 variety).

Nutrient	Unit	per 100 g
Proximates		
Water	g	10.01
Energy	kcal	338
Protein	g	13.18
Total lipid (fat)	g	1.81
Carbohydrate, by difference	g	73.14
Fiber, total dietary	g	14.6
Minerals		
Calcium, Ca	mg	35
Iron, Fe	mg	2.59
Magnesium, Mg	mg	153
Phosphorus, P	mg	321
Potassium, K	mg	466
Sodium, Na	mg	2
Zinc, Zn	mg	2.66
Vitamins		
Vitamin C, total ascorbic acid	mg	0
Thiamin	mg	0.378
Riboflavin	mg	0.132
Niacin	mg	2.86
Vitamin B-6	mg	0.403
Folate, DFE	µg	74
Vitamin B-12	µg	0
Vitamin A, RAE	µg	0
Vitamin A, IU	IU	0
Vitamin E (alpha-tocopherol)	mg	0.9
Vitamin D (D2 + D3)	µg	0
Vitamin D	IU	0
Lipids		
Fatty acids, total saturated	g	0.318
Fatty acids, total monounsaturated	g	0.183
Fatty acids, total polyunsaturated	g	0.794
Cholesterol	mg	0

DFE, dietary folate equivalents; RAE, retinol activity equivalent; data is from http://ndb.nal.usda.gov/ndb/search; accessed on May 13th, 2017; please be noted that only 1 triticale variety was analysed.

2.1. Carbohydrates

Carbohydrates, as the major components of triticale, account for over 70% of the dry weight. The influence of genetics and developing grain on the total carbohydrate content of triticale was studied (Cornejo-Ramírez et al., 2015; Cornejo-Ramírez, Ramírez-Reyes, Cinco-Moroyoqui, Rosas-Burgos, et al., 2016). Complete triticale has the genomic composition of AABBRR (hexaploid) or AABBDDRR (octaploid), whereas the genomic constitutions of substituted triticale are AABBDR or AABBDDDR (Cornejo-Ramírez et al., 2016). Complete triticale (3 genotypes) contained a higher amount of carbohydrates (average: 80.4%) than substituted triticale (3 genotypes) (average: 73.3%) (Cornejo-Ramírez et al., 2015, 2016). For both types of triticale, the total carbohydrate content in developing triticale increased gradually from ~20–30% at 7 days after anthesis (DAA) to ~70–80% at 40 DAA (Cornejo-Ramírez et al., 2016). The results on the total carbohydrate content of triticale generally agreed with previous reports (McGoverin et al., 2011). The influence of growing and genetics on the total carbohydrate content of triticale was also reflected by the changes in the total content of starch which is the major component of carbohydrates, as described below.

2.1.1. Starch

2.1.1.1. Content and composition. A number of recent studies reported the total starch content of triticale (Cornejo-Ramírez et al., 2015; Frás et al., 2016; Makowska, Szwengiel, Kubiak, & Tomaszewska-Gras, 2014). For example, the starch content of triticale grains (9 genotypes) ranged from 60.8 to 67.6%. Upon milling, the starch content of the resulting flours ranged from 68.2 to 77.5% (Frás et al., 2016). Starch contents of 5 Polish genotypes were similar (63–65.8%) (Makowska et al., 2014). The starch contents of triticale (11 genotypes) ranged from 63.3 to 68.8%, which appeared to be similar to that of wheat (Dennett, Wilkes, & Trethowan, 2013). Starch contents of triticale (4 genotypes) ranged from 61 to 75.9%. One study showed that there appeared to be no difference in starch content between substituted and complete triticale genotypes (Navarro-Contreras et al., 2014). In contrast, two other studies showed that complete triticale contained a higher amount of starch (e.g., average of 3 genotypes: 60.6%) than substituted triticale (e.g., average of 3 genotypes: 52.2%) (Cornejo-Ramírez et al., 2015, 2016). The difference may be due to the different genetics of the samples. Total starch content in developing triticale increased gradually from ~15–24% at 7 days after anthesis (DAA) to ~55–63% at 40 DAA (Cornejo-Ramírez et al., 2016). Effects of water stress during triticale development on starch properties were studied (He, Goyal, Laroche, Zhao, & Lu, 2012). Triticale were grown in soil with 3 different levels of moisture (10–60%). The starch content was decreased by up to 55% by severe water stress, while the expressions of starch biosynthetic genes were reduced greatly (He et al., 2012).

Amylose is a major component of starch and plays an important role in functional properties of starch. A few studies reported the amylose