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COMPREHENSIVE REVIEW

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Ancient wheat and health: a legend or the reality? A review on KAMUT khorasan wheat

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ABSTRACT

After WWII, the industrialized agriculture selected modern varieties of *Triticum turgidum* spp. *durum* and spp. *aestivum* (durum wheat and common wheat) based on higher yields and technological characteristics. Nowadays, the use of whole ancient grains and pseudo cereals is considered nutritionally important. How ancient grains have positive effects is not entirely known, the fragmentation of the scientific knowledge being also related to the fact that ancient grains are not a homogeneous category. The KAMUT® trademark indicates a specific and ancient variety of grain (*Triticum turgidum* ssp. *turanicum*, commonly khorasan wheat), and guarantees certain attributes making studies sufficiently comparable. In this work, studies on KAMUT® khorasan wheat have been systematically reviewed, evidencing different aspects supporting its benefits. Although it is not possible to establish whether all ancient grains share these positive characteristics, in total or in part, this review provides further evidences supporting the consumption of ancient grains.

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KAMUT khorasan wheat; ancient grains; whole grains; ancient wheat

Introduction

Grains are seeds from plants of the Gramineae family (such as wheat, corn, rice, barley, oat and rye) that have been the basis for human nutrition for thousands of years. Grains are fundamental for sustenance, both for their nutritional value and for their chemical properties that allow for a variety of uses in the food industry. Last, but not least, grains can be stored for long periods, and easily transported.

Wheat was one of the first domesticated food crops, and for about 8000 years it has been the basic staple food of the major civilizations of Europe, West Asia and North Africa. Today, wheat is grown on more land area than any other commercial crop and continues to be the most important food grain source for humans (Curtis 2002).

The most commonly used types of wheat, *Triticum turgidum* ssp. *durum* (or durum wheat), used to make pasta, and *Triticum turgidum* ssp. *aestivum* (or common wheat), used to make bread, originated thousands of years ago through naturally occurring hybridization of their progenitors. In the last 60 years, there has been an ever-increasing number of the varieties available, for both durum wheat and common wheat, while ancient varieties of this cereal have been largely forgotten or lost.

Ancient wheat is loosely defined as wheat that was used by ancient civilizations. Usually ancient wheat is considered to include einkorn, emmer, khorasan and spelt. Another term used to describe wheat commonly grown in the period between ancient wheat and modern wheat is heritage wheat. This wheat consists of varieties selected from either ancient wheat or wild wheat. Ancient wheat and heritage wheat generally consist of land races, which mean they were made up of many closely related strains. Land races have a huge diversity in their populations giving them great advantages in facing extremes in climate fluctuation and disease and insect pressure. The reason for this is that this diverse population contains strains which vary in their susceptibility to the aforementioned challenges. Modern wheat, by contrast is made up of homogeneous strains, which are the result of intensive breeding programs generally starting after WWII. During this period, the industrialization of agriculture began to include high inputs of

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chemicals to help increase yields and a focus on bread in and pasta production, which increased speed and efficacy of the process. Especially the size of the loaf of bread was of great importance therefore, one important goal was to increase the number of loaves of bread from each kg of flour used. So pure strains of wheat were developed with greater yield potential and greater loaf volume capacity.

In the last decade, some of these "ancient grains", not subjected to extensive genetic improvements, have been reintroduced, and the growing awareness regarding foods considered natural and healthy have further increased the interest in alternative cereals. This interest is also associated with the fact that some of them are reported to be better tolerated by individuals that suffer from intolerance or allergies to modern wheat (Molberg et al. 2005; Spaenij-Dekking et al. 2005).

Ancient grains (khorasan wheat, barley, spelt, rye, millet, oat and sorghum) and pseudo cereals (i.e. quinoa, amaranth and buckwheat) are considered healthy due to their higher content of certain components (Wijngaard & Arendt 2006) and to their common use as whole grains. Whole grains contain higher amounts of positive components compared to refined grains. Most importantly, dietary fiber, vitamins and minerals, but also other bioactive molecules such as omega 3 fatty acids, prebiotic oligosaccharides, phytosterols, polyphenols, etc., and probably the interaction of all the components rather than each individual one gives whole grains their nutritional value (Slavin et al. 2001).

Epidemiological studies have scientifically proven that regular eating of whole grains positively affects human health, because it reduces the risk of type 2 diabetes (Maki & Phillips 2015) and manages obesity (Giacco et al. 2011). It is also linked to both a lower cardiovascular mortality rate in the elderly and a reduction in colon cancer cases (Truswell 2002; Sahyoun et al. 2006; Gil et al. 2011).

Despite dietary guidelines all over the world are recommending the inclusion of whole grains, the knowledge of the healthy effect of whole ancient grains is fragmented and based more on the evaluation of the properties of the main chemical components than on the effect of the individual ancient grain on those who have ingested it. In addition, compositional differences existing among different ancient grains and among varieties of the same grain (Gawlik-Dziki et al. 2012; Carvalho et al. 2015), and the strong influence of agronomic and environmental factors on the level of phytochemicals in plants (Danesi et al. 2014) could make difficult to generalize results obtained in a specific study.

In this respect, KAMUT® khorasan wheat represents an interesting exception, since it is a specific and ancient variety of grain (*Triticum turgidum* ssp. *turanicum*, commonly called khorasan wheat). KAMUT® is a registered trademark of Kamut International, Ltd. (Big Sandy, MT) and Kamut Enterprises of Europe (Bologna, Italy), bvba, and the trademark guarantees certain attributes, mainly a protein content of 12–18% and a selenium content between 400 and 1000 ppb, and several quality specifications related to growing conditions. For example, the grain must be always grown certified organic and never hybridized or genetically modified (Quinn 1999). This makes possible the comparison among studies. The chemical composition of KAMUT® khorasan wheat, durum wheat and common wheat is reported in Table 1.

Table 1. Chemical composition and energy of KAMUT® khorasan wheat, common wheat and durum wheat.

	KAMUT® khorasan wheat	Soft wheat	Durum wheat
Water (g/100 g)	11.07	10.42	10.94
Energy (Kcal/100 g)	337	340	339
Proteins (g/100 g)	14.54	10.69	13.68
Total lipid fat (g/100 g)	2.13	1.99	2.47
Saturated (g/100 g)	0.196	0.368	0.454
Monounsaturated (g/100 g)	0.213	0.227	0.344
Polyunsaturated (g/100 g)	0.621	0.837	0.978
Cholesterol (mg/100 g)	0	0	0
Carbohydrate (g/100 g)	70.58	75.36	71.13
Fibres total (g/100 g)	11.1	12.7	n.d.
Sugars (g/100 g)	7.84	0.41	n.d.
Vitamin C (mg/100 g)	0	0	0
Thiamine (mg/100 g)	0.566	0.410	0.419
Riboflavin (mg/100 g)	0.184	0.107	0.121
Niacin (mg/100 g)	6.375	4.766	6.738
Vitamin B_6 (mg/100 g)	0.259	0.378	0.419
Folic acid (μg/100 g)	n.d.	41	43
Vitamin B_{12} (μg/100 g)	n.d.	0	0
Vitamin A (μg/100 g)	1	0	0
Vitamin E (mg/100 g)	0.61	1.01	n.d.
Vitamin D (μg/100 g)	n.d.	0	0
Vitamin K (μg/100 g)	1.8	1.9	n.d.
Calcium (mg/100 g)	22	34	34
Iron (mg/100 g)	3.77	5.37	3.52
Magnesium (mg/100 g)	130	90	144
Phosphorus (mg/100 g)	364	402	508
Potassium (mg/100 g)	403	435	431
Sodium (mg/100 g)	5	2	2
Zinc (mg/100 g)	3.68	3.46	4.16

United States Department of Agriculture. USDA Food Composition Database. Available from: http://ndb.nal.usda.gov/.

In this work, studies performed to evaluate the nutritional, technological and healthy characteristics of KAMUT® khorasan wheat compared to modern wheat have been systematically reviewed, in the attempt to go deeper inside the scientific basis for the possible exploitation of this ancient grain to produce food having an enhanced nutritional value.

Search strategy

The detailed selection process is presented in Figure 1. First access in PubMed was performed on 30

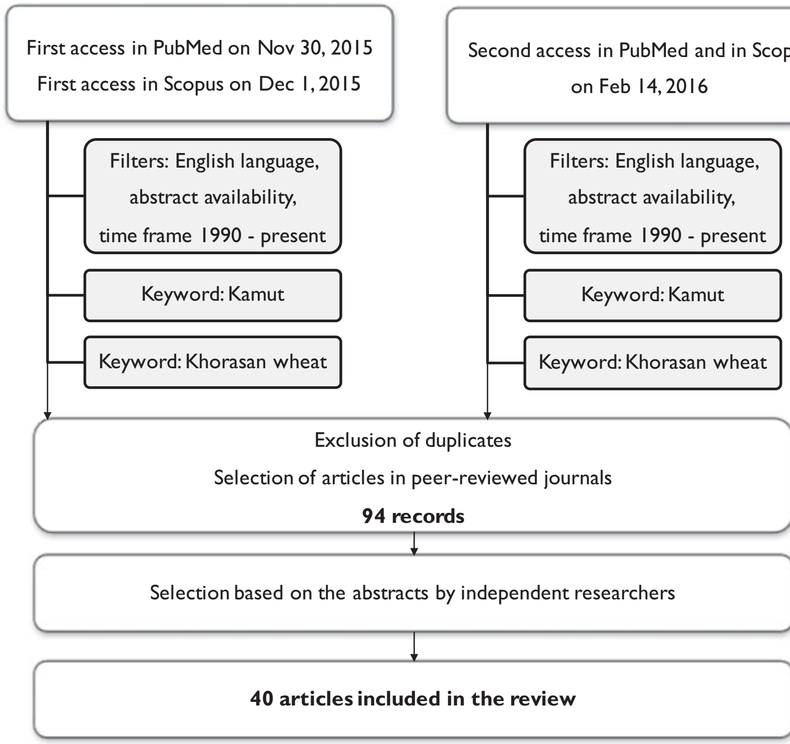

Figure 1. Flow diagram of search strategy and study selection.

November 2015 using "Kamut" as keyword and English language, abstract availability and publication in the year 1990-present as filters. The timeframe period of the search was selected based on the year of registration of KAMUT® as a trademark. Twenty-two records were retrieved. Search was performed again using "Khorasan wheat" as keyword and the same filters, and it retrieved 12 records, six of them in common with the previous search. PubMed search was performed again on 10 February 2016, and four additional records, three for Kamut and one for khorasan wheat were added to the list. First search on Scopus was performed on 1 December 2015 using the same keywords and filters. A second search was performed on 10 February 2016.

Lists were compared to avoid duplicates, and articles published in peer-reviewed journals were selected, so obtaining 94 records. Records were then checked based on their abstract by independent researchers, and those out of the scope of this review, as well as articles reporting data on khorasan wheat but not specifically on KAMUT® wheat were excluded. In the end, 40 articles were included in the review.

Results and discussion

Technological and nutritional aspects

The organoleptic and nutritional properties of grain products depend on the flour used for their production. The physical result of the flour is extremely important in the final product, especially in baked goods, and therefore one of the primary limitations in the use of flour made from something other than wheat is its inadequate chemical properties. The partial or complete substitution of normal flour with flour from ancient grains could add nutritional value to the final products, provided that the physical and sensory characteristics of the substituting flour are equal or better than those of wheat so that public acceptance is not deterred.

The suitability of KAMUT® khorasan wheat has been positively ascertained in the production of bread (Piergiovanni et al. 2009), tortillas (Carini et al. 2010) and cookies (Chandi et al. 2015). In tortillas, the substitution of regular flour with KAMUT® khorasan wheat flour slightly modified flour reaction to water (Serventi et al. 2009), but the physiochemical properties of the finished product were the same, even in products with a long shelf-life (180 days) (Carini et al. 2010). In cookie production, the flour made from KAMUT® khorasan wheat appeared to be able to substitute common wheat for up to 50% without causing qualitative physical alterations in the product's properties (Chandi et al. 2015). Furthermore, bread made with a mix of ancient cereals, including KAMUT® khorasan wheat, demonstrated comparable sensorial and physical properties as that of wheat flour

(Angioloni & Collar 2011). The physicochemical and metabolomic characteristics of KAMUT® khorasan and durum wheat fermented dough were investigated by Balestra et al. (2015), who found KAMUT® flour to be more suitable than durum wheat for the fermentation processes tested, especially at acidic conditions.

Studies reported above indicate that KAMUT® khorasan wheat enjoys great versatility as a raw material because it is suitable for several consumer uses. In addition, consumers enjoy products made with the KAMUT® khorasan wheat (Holmer et al. 2012), and appreciate numerous quality attributes (e.g. it is organically grown, it is managed according to a global value-enhancement strategy) featured by KAMUT® wheat (Canavari et al. 2009).

According to Canavari et al. (2009), Italian large-scale retail chains are deeply interested in marketing this type of product. At present, Italy is the largest EU consumer of KAMUT® and imports approximately 70% of all the KAMUT® wheat exported in Europe. Most of the Italian KAMUT®-based products are exported into other EU countries, while in Germany, France and Belgium nearly all the imported KAMUT® grains are domestically consumed.

The use of KAMUT® khorasan wheat flour as a substitute for other ingredients can contribute to the improvement of the nutritional value of the final product. Bread made with KAMUT® khorasan wheat flour had more carotenoid and was richer in protein compared to breads made with modern wheat (Pasqualone et al. 2011). Similarly, total phenolics, total flavonoids and antioxidant capacity were higher in spelt and KAMUT® flakes and muesli than in corresponding conventional products, although lower than in products made with Dickopf wheat and red wheat (Sumczynski et al. 2015). In addition, products made with spelt and KAMUT® wheat had the highest protein level (Sumczynski et al. 2015).

Shewry and Hey (2015) carried out an extensive literature review in order to determine whether ancient wheat species differ from common wheat in a range of components that have established or proposed benefits to human health. Among studies included in the review, Abdel-Aal el and Rabalski (2008) reported a higher concentration of total phenolics in KAMUT® wheat than in 10 common wheat cultivars. This could be due to the low polyphenol oxidase found in KAMUT® flour compared to other 59 whole meal flours (Hidalgo et al. 2013). In addition, a higher content of total carotenoids in KAMUT® wheat compared with common wheat was reported (Abdel-Aal el et al. 2007). The major component was lutein, which was present at 5.77 mg/g concentration compared with a mean of 2.06 mg/g in four common wheat cultivars. The high content of lutein was confirmed by other studies (Abdel-Aal el et al. 2002; Hidalgo et al. 2006; Abdel-Aal el & Rabalski 2008). On the contrary, total tocols were lower in KAMUT® wheat than common wheat cultivars (Hidalgo et al. 2006; Abdel-Aal el & Rabalski 2008).

The evaluation of the functional components of 10 Italian durum wheat cultivars highlighted remarkable differences between modern and old genotypes (Dinelli et al. 2009). Besides no significant differences among investigated cultivars were detected as regards the amounts of total phenolic and flavonoid compounds, the qualitative phytochemical profile between old and modern varieties was remarkably diverse. Ancient wheat varieties showed a mean number of phenolic compounds and isomer forms significantly higher than in modern genotypes. As examples, coumarin was detected only in the free phenolic fraction of the old wheat genotype KAMUT® khorasan, and procyanidin B3 and occurred in the free phenolics of Iride and KAMUT® khorasan wheat.

The putative functionality of KAMUT® khorasan wheat could be not only connected to its high content of phenols and carotenoids, but also to the presence of other molecules such as bioactive peptides, small protein fragments that have positive effects on body functions in humans (Kitts & Weiler 2003). In the study by Coda et al. (2012), a pool of selected lactic acid bacteria was used for the sourdough fermentation of various cereal flours. The highest radical-scavenging activity of water/salt-soluble extracts was found for whole wheat, spelt, rye and KAMUT® sourdoughs demonstrating that selected lactic acid bacteria have the capacity to synthesize antioxidant peptides during the sourdough fermentation of these cereal flours.

The health-promoting effects of wholemeal flours could be related to the presence of other minor components. Pedersen et al. (2011) evidenced the presence of benzoxazinoids, a group of natural compounds having documented physiological effects, in hydrothermally processed grains of KAMUT®, a commercial variety of rye (*Secale cereale* cv. Picasso) and an old Nordic rye landrace (*Secale cereale*, Svedjerug), as well as in bread baked with flour milled from those grains.

There is ample evidence that diet can modulate both composition and functionality of the human gut microbiota, in a complex and dynamic interplay crucial for maintaining the host-microbiota mutualism (Cotillard et al. 2013). KAMUT® wheat could be a special raw material for improving the prebiotic properties of wheat-based products. Although the content of soluble dietary fiber was found lower in KAMUT®

flour than in grains of *Triticum polonicum* (average of nine spring lines) (Wiwart et al. 2013), it was higher than in the Italian modern durum wheat variety Claudio (Di Silvestro et al. 2014). In addition, KAMUT® fibers have been shown to have a prebiotic effect and to promote the growth of Lactobacillus and Bifidobacterium (Marotti et al. 2012). Taneyo Saa et al. (2014) described for the first time the effect of KAMUT® khorasan wheat on the human gut microbial ecology. According to their results, the KAMUT® khorasan-based diet was mainly characterized by the release of short fatty acids and phenol compounds, as well as by a slight increase in health-promoting mutualists of the gut microbiota in comparison to whole durum wheat adopted as a control diet.

In vitro and animal studies

In the study by Valli et al. (2016), cookies baked with three different whole grains flours (KAMUT® khorasan wheat grown in North America, khorasan wheat grown in Italy, and a modern durum wheat) and two fermentation methods (standard and lactic fermentation) were digested *in vitro* and supplemented to cultured liver cells. Cells were then exposed to either an oxidative or an inflammatory stress by adding H_2O_2 or lipopolysaccharides. Overall, cell supplementation with the bioaccessible fraction of all digested cookies evidenced protective activities towards oxidative and inflammatory stress; however, the extent of this protection varied from flour to flour (KAMUT® khorasan > Italian khorasan > durum wheat).

The aim of the study by Gianotti et al. (2011) was to evaluate in rats whether a diet comprised exclusively of bread made from whole modern durum flour or KAMUT® khorasan wheat flour could affect the response to the oxidative stress induced by the administration of doxorubicin. Two different bread-making processes were used for whole grain KAMUT® khorasan, sourdough and baker's yeast, while whole grain durum wheat bread was made using standard fermentation (baker's yeast) only. The authors concluded that diet based on the ancient cereal is able to supply a variety of nutrients and bioactive components that improve the organism's ability to defend itself against oxidative stress, independent of the type of fermentation used to make the bread. Using a similar experimental design, Benedetti et al. (2012) confirmed these findings and demonstrated that a diet based on bread made from KAMUT® khorasan wheat is able to increase plasma antioxidant concentration and antioxidant enzyme activity.

In addition, histologic tests on the liver evidenced an inflammatory status in rats fed modern durum wheat and not in rats fed KAMUT® khorasan wheat. Feeding rats with pasta made from KAMUT® khorasan wheat or durum wheat obtained similar results (Carnevali et al. 2014). After 7 weeks, all of the rats fed modern durum wheat pasta showed alteration in the morphology of their duodenums' mucosa, with an unusual flattening of the intestinal villus and infiltration of lymphocytes, and an increased volume of lymph follicles in the spleen and lymph nodes. These signs of inflammation were not present in the rats fed pasta made from KAMUT® khorasan wheat.

Human intervention trials

Five intervention trials involving human volunteers are reported in the literature. The first one (Scazzina et al. 2008) evidenced that the incorporation of carrots, soy, and whole KAMUT® meal in a standard wheat tortillas formulation results in a product with a lower glycaemic index (GI) and a relatively high total antioxidant capacity. However, the GI of tortillas made with KAMUT® only did not differ from standard tortillas, suggesting the main contribution or the synergistic action of other ingredients.

In the other trials, products made from KAMUT® khorasan wheat were compared to products made with modern common and durum wheat. Both the KAMUT® khorasan and the control wheat were cultivated in organic agriculture. Semi-whole wheat semolina and flour from KAMUT® and modern wheat were similarly processed to obtain pasta and baked products. All studies were randomized, double-blinded, crossover trials with two intervention phases in which subjects were assigned to consume either the KAMUT® or the control wheat.

The first study (Sofi et al. 2013) involved 22 healthy volunteers carrying risk factors for cardiovascular diseases. Volunteers were randomly divided into two groups, assigned to consume the KAMUT® khorasan or control grain products made from organic semi-whole-wheat for 8 weeks. Then, after an 8-weeks washout, groups were crossed over for additional 8 weeks. The consumption of products made with KAMUT® khorasan wheat resulted in a significant reduction in blood total cholesterol (–4.0%), LDL cholesterol (–7.8%) and glucose levels (from 81.1 to 78.1 mg/dL). Redox status, measured by the blood level of thiobarbituric acid reactive substances (TBARS) and carbonyl levels was significantly improved only after the KAMUT® intervention phase. Furthermore, consumption of KAMUT® khorasan products resulted in a significant decrease of the level of pro-inflammatory cytokines: tumor necrosis factor α (TNFα, –34.6%), interleukin 6 (IL6, –23.6%), interleukin 12 (IL12, –28.1%) and vascular endothelial growth factor (VEGF, −10.5%). No changes were observed for the same patients after eating the control products made from modern wheat.

In the second study (Sofi et al. 2014), 20 participants classified with moderate inflammatory bowel syndrome (IBS) were divided into two groups, the first receiving KAMUT® khorasan products and the second modern wheat products for 6 weeks. After a 6-week washout period, volunteers were crossed over for additional 6 weeks. The IBS-GAI (Global Assessment of Improvement) and the IBS-SSS (Symptom Severity Scale) were used to evaluate IBS symptoms, and evidenced significant improvements in patients consuming KAMUT® khorasan products. A concomitant significant reduction in circulatory pro-inflammatory cytokine levels, including interleukin 6 (–36.2%), interleukin 17 (–23.3%), interferon γ (–33.6%) and VEGF (–23.7%) was detected after the KAMUT® khorasan wheat intervention phase.

The third trial (Whittaker et al. 2015) involved 22 patients diagnosed with acute coronary syndrome with a cross over study design with two intervention phases (8 weeks each, with an 8 week wash-out period) in which subjects were assigned to consume either the KAMUT® khorasan or the control wheat. Even in this study consumption of products made with KAMUT® khorasan wheat resulted in a significant amelioration of blood total cholesterol (–6.8%), LDL cholesterol (–8.1%), glucose (–8.0%) and insulin level (–24.6%) from baseline levels. Moreover, a significant reduction in reactive oxygen species (ROS), lipoperoxidation of circulating monocytes and lymphocytes, and circulating TNFα was detected after consumption of KAMUT® products, while no changes were observed after consumption of modern wheat products.

Last, the study by Whittaker et al. (2016) was a randomized, double-blinded, crossover trial aimed at testing whether a replacement diet with KAMUT® khorasan wheat products and/or control wheat products could provide additive benefits to type 2 diabetes mellitus patients. Even in this study, compared to baseline a reduction in blood total (–3.7%) and LDL cholesterol (–3.4%), insulin (–16.3%) and glucose (–9.1%), as well as a significant reduction in circulating levels of ROS, VEGF, and interleukin 1 receptor antagonist (IL1Ra) were observed after consumption of KAMUT® products. No significant differences from baseline were noted after the modern wheat intervention phase.

Celiac disease and non-coeliac gluten sensitivity

Celiac disease (CD) is a chronic autoimmune disease of the intestine caused by exposure to gluten in genetically predisposed subjects (Ludvigsson et al. 2013). In Europe, South America, Australasia and the USA, between 0.5% and 1% of the population are affected, and a high percentage of celiac cases goes undiagnosed because of the large variety of symptoms (Martucci et al. 2002). The only treatment for CD is eliminating gluten from the diet. However, this is very difficult because in many food products other than pasta and baked goods contain gluten, which is also used as an excipient in drugs and vitamin supplements (van den Broeck et al. 2010). Furthermore, gluten-free products (GFPs) are considered of lower quality and poorer nutritional value compared to the gluten-containing counterparts. GFPs often have a greater carbohydrate and lipid content than their gluten containing equivalents, and some commercially available GFPs have a lower content of folates, iron and B vitamins. In addition, some studies have reported that GFD is associated with a lower intake of dietary fibre (Penagini et al. 2013).

At present, it is unknown if all wheat varieties are equally toxic to individuals with CD. In an attempt to identify grains less toxic to celiac patients, several scientists strongly focused on the analysis of grains considered forerunners of modern grains. Gregorini et al. (2009) and Colomba and Gregorini (2012) reported that both Graziella Ra and KAMUT® khorasan wheat are CD toxic as the modern durum accessions, and contain greater amounts of α-gliadin. Similarly, results by Šuligoj et al. (2013) underlined strongly the need for all cereals from the tribe Triticeae to be considered CD toxic.

Notwithstanding, KAMUT® khorasan wheat has been showed to have a lower percentage of epitopes than Senatore Cappelli, a heritage durum wheat selected and introduced over 100 years ago, and modern Claudio durum wheat and Manitoba common wheat (Valerii et al. 2015). The concentration of gliadin proteins carrying allergenic epitopes among the total protein pattern can influence the inflammatory response. Valerii et al. (2015) evidenced that wheat proteins induce an overactivation of the pro-inflammatory chemokine (C-X-C motif chemokine 10, CXCL10) in cultured peripheral blood mononucleated cells (PBMC) from subjects with non-celiac gluten sensitivity (NCGS), and overactivation level depends on the cereal source from which proteins are obtained. In this study, chemokine CXCL10 activation was higher after exposure to modern than ancient grain protein. This could explain, at least in part, why KAMUT® wheat is reported to be better tolerated by individuals suffering from NCGS (Molberg et al. 2005; Spaenij-Dekking et al. 2005).

NCGS is characterized by intestinal and extra intestinal symptoms that occur after the ingestion of gluten-containing food in subjects in whom CD and wheat allergy have been ruled out (Tovoli et al. 2015). Gluten may not be the only triggers of NCGS, and different wheat proteins such as wheat amylase and trypsin inhibitors could contribute to the origination of symptoms (Inomata 2009).

Fermentable oligosaccharides, disaccharides, and monosaccharides and polyols (FODMAPs) can provoke gastrointestinal symptoms through mechanisms involving gut microbiota, gas production and fermentation (Halmos et al. 2014). Some grains and cereals are particularly rich in FODMAPs, and recent studies have shown that a diet low in FODMAPs results in improved symptoms in NCGS patients, supporting the hypothesis of a major role of FODMAPs compared to gluten (Biesiekierski et al. 2013). Although whole-grain flour from ancient wheat inhibited yeast fermentation, fructan levels were reported similar bread and pasta made with KAMUT® khorasan wheat and emmer and with modern wheat (common wheat; durum) (Gélinas et al. 2016).

Conclusions

The development of studies and research aimed to test the effectiveness of preventive and protective nutrients and food components has clarified many aspects of the complex relationship between nutrition and well-being. Notwithstanding, often a few things are forgotten, first that our diet is based on foods and not on individual molecules. If on one hand it is useful to prove that a certain component has a positive effect in the prevention of a disease, it is also important to identify which foods contain it. Foods are complex matrices in which that component is not present alone, but along with many other molecules that could have additive, synergistic or antagonist effect. In addition, processing often modifies concentration and bioavailability of the component. Finally, yet importantly, foods having a high consumption frequency have the highest possibility to allow the introduction of the effective dose of the component. In one word, the relationship among food components, food and health must be studied with a foodomics vision (Bordoni & Capozzi 2014).

Whole ancient grains in general, and KAMUT® khorasan wheat in particular, are an example of synergism among different components (Gianotti et al. 2011), and can be transformed into a large variety of products that are consumed every day. Studies reported in this review point out the health-promoting properties of KAMUT® khorasan wheat, not evident in commercial modern varieties. At this stage, it is not possible to establish whether the health effects are specific for KAMUT® khorasan wheat or all ancient grains share them. At present, further scientific evidences are needed to consider KAMUT® khorasan-based products as functional foods, but results are promising and there are several elements of great interest that challenge the scientific community to deepen the scientific knowledge about this ancient grain in particular and ancient grains in general.

Disclosure statement

The authors report no potential conflict of interest.

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