Scientific Bulletin. Series F. Biotechnologies, Vol. XXIV, No. 1, 2020
ISSN 2285-1364, CD-ROM ISSN 2285-5521, ISSN Online 2285-1372, ISSN-L 2285-1364

TRENDS AND CHALLENGES IN GLUTEN-FREE BAKING PRODUCTS INGREDIENTS: A REVIEW

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Abstract

Nowadays gluten-free (GF) products represent a growing sector in the food industry due to the increasing interest of gluten-intolerant and also for healthy people who are preoccupied in special diets and a healthy lifestyle. This paper reviews recent studies about different ingredients used in gluten-free baking products. The main flour sources for developing gluten-free products are cereals (rice, corn, sorghum), pseudo-cereals (buckwheat, quinoa, amaranth), minor cereals (teff, millet), and legumes (soybean, chickpea, lentil, pea). Apart from these, there are other types of flours used in baking gluten-free products from seeds (flax seeds, chia seeds, pumpkin seeds), nuts (almonds, hazelnuts, chestnuts, walnut, cashew nut), and tubers (arrowroot, tapioca, jicama, taro, potato). This research focused on the literature review regarding identification and quality parameters of various flours and ingredients used in the manufacture of gluten-free baking products.

Key words*: baking products, cereal flour, gluten-free, gluten-free flours.*

INTRODUCTION

Celiac disease (CD) also called gluten enteropathy is an inflammatory condition of the small intestine. This disease affects approximately 1% of the global population (Vici et al., 2016). The clinical symptoms of celiac disease are different from patient to patient, depending on age, duration and the extent of extra intestinal manifestations (Saturni et al., 2010).

CD develops on genetically predisposed subjects when they have an immune system abnormal reaction due to wheat gluten, barley and rye prolamins (Picascia et al., 2016). The consequences of the above reactions are the inflammation and damage to the lining of the small intestine which reduce the absorption of different nutrients such as calcium, iron, vitamins A, D, E, K and folate (Health Canada, Celiac Disease - The Gluten Connection, 2008). Based on data from a recent study, published by World Gastroenterology Organization, in Romania, the incidence of celiac disease among patients with diabetes is 3.9% (WGO, 2016).

Nowadays, more and more people even if they don't suffer from celiac disease are interested in gluten-free products because they want a healthy lifestyle. Besides satisfying hunger and providing the nutrients for humans, healthy eating should also prevent nutrition-related diseases and improve physical and mental well-being of the consumers (Jnawali et al., 2016).

There is no treatment for celiac people so far, the only solution is following a gluten-free diet which requires significant patient education, motivation and follow-up (Rubio-Tapia et al., 2013). Gluten-free products have usually lower quantities of different nutrients like fibre, magnesium and folic acid than gluten-containing ones.

There are other things that make gluten-free products hard to replace. Without gluten, doughs lack cohesiveness, elasticity and baking quality. This fact negatively influences the way of dough handling (Bendera & Schonlechnera, 2019). The risk of suffering from celiac disease is higher for people who have a first degree relative who suffers from it (Murray, 2005; Rubio-Tapia et al., 2008).

The highest risk is for monozygotic twins, next in human leukocyte antigen (HLA) - matched siblings, and then parents and children of patients with CD (Rubio-Tapia et al., 2008). The

lower probability is for 2nd degree relatives (Strong recommendation, high level of evidence). When more than one person is already diagnosed with CD in the family, it is recommended to test the whole family, including the 2nd degree relatives (HLA-DQ2/DQ8) (Rubio-Tapia et al., 2013).
Because of the increasing amount of people who suffer from wheat-related diseases and the desire for healthy eating and lifestyle, food industry began to promote new products made from cereals, other than wheat or rye on the market (Collar, 2014).

MATERIALS AND METHODS

Web of Science database was electronically searched for articles published in the last 20 years. The literature search included as document type: research article and review, on the topics: „gluten-free products", „celiac disease", „gluten-free ingredients", „gluten-free challenges" and the article title containing key words regarding gluten-free cereal and flour types.

RESULTS AND DISCUSSIONS

A gluten-free diet supposes a complete change in life style and a big challenge for celiac people due to the presence of gluten in most types of food products: breads, breakfast cereals, pasta, biscuits, cookies, cakes, bagels, soups (Jnawali et al., 2016).
The most common ingredients used for baking gluten-free products are corn and rice (Gobbettia et al., 2018).
However, a long list of pseudo-cereals, seeds, legumes and nuts (e.g. amaranth, quinoa, millet, sorghum, flax and chickpeas) could replace gluten and integrate and/or substitute the main GF ingredients, all variously improving the nutritional quality of gluten-free diet (GFD) (Kupper, 2005).
Nowadays, pseudo-cereals represent an alternative used for the development of gluten-free bakery products. Pseudo-cereals are edible seeds which belong to dicotyledonous species and they resemble to the physical appearance and high starch content with true cereals. People are interested in pseudo-cereals because these are crops which adapt to different environments from tropical to temperate climatic conditions. The most important pseudo-cereals are quinoa, amaranth and buckwheat (Martínez-Villaluenga et al., 2020).
It is a real challenge to develop gluten-free products because celiac people have various nutrient deficiencies (Hallert et al., 2002). Studies have shown that adults which are suffering from celiac disease and follow a gluten-free diet have significantly lower weight, body mass index, fat and lean body mass than control subjects (Ciacci et al., 2002). A gluten-free diet assumes an alimentation with a lower intake of dietary fibre than a diet which contains gluten (Vici et al., 2016), so using pseudo-cereals represents a good alternative to wheat flour.
These are an important source of minerals (calcium, iron and zinc), vitamins and phytochemicals such as saponins, polyphenols, phytosterols, phytosteroids, and betalains which presents a real potential health benefit (Martínez-Villaluenga et al., 2020). The major nutritional components of pseudo-cereals grain are carbohydrates which vary between 60 and 80% of the seed dry weight (Joshi et al., 2018; Joshi et al., 2019; Shukla et al., 2018). Buckwheat, quinoa, amaranth have a different content of amylose 18.3-47% of total starch, 11-12% of total starch and 7.8-34.3% of total starch, respectively (Repo-Carrasco-Valencia & Arana, 2017).
Starch can be rapidly digestible, slowly digestible or resistant, depending on how easily it is broken down in the gut (Lockyer & Nugent, 2017). Resistant starch (RS) is known for its health benefits as it cannot be digested and absorbed in the small intestine reaching the colon where it is slowly fermented by microorganisms to produce short chain fatty acids (Lehmann & Robin, 2007). According to EFSA (2011), starchy food should contain at least 14% of RS on a total basis to provide health benefits. The highest levels of resistant starch are found in common and tartary buckwheat (27-33.5%) (Skrabanja et al., 1998; Zhou et al., 2019).
Pseudo-cereals are also rich in dietary fibre. Total fibre content varies from 7.0 to 26.5% for quinoa, 2.7 to 17.3% for amaranth and 17.8% for buckwheat, which is in the same range as common cereal grains (Joshi et al., 2019; Joshi

et al., 2018; Lamothe et al., 2015). Quinoa and amaranth also contain a higher content of folic acid, approximately 78 mg/100 g and 102 mg/100 g, respectively, in comparison to wheat (approximately 40 mg/100 g).

The protein quantity and profile depend on genotype and environmental conditions. Compared to pseudo-cereals, cereals have inferior nutritional value. The protein content varies from 9.1-16.7% for quinoa, 13.1-21.5% for amaranth and 5.7-14.2% for buckwheat (Joshi et al., 2019; Joshi et al., 2018; Nowak et al., 2016; Pereira et al., 2019; Shukla et al., 2018; Thanh-Tien et al., 2018), making them key contributors to human protein intake (Martínez-Villaluenga et al., 2020). The gluten-free bread making technology is significantly different from the process of standards wheat breads.

Gluten-free doughs are much less cohesive and elastic than wheat dough. They are extremely smooth, too sticky, less pasty, and difficult to handle. According to Houben et al. (2012) most gluten-free doughs have higher water content and have a more fluid-like structure comparable to the batter of a cake. A shorter mixing, proofing, and baking times are needed, compared to wheat doughs. Gluten-free breads are characterized by smaller volumes, firmer crumbs, and softer crusts. Besides these, other disadvantages of gluten-free bread are: short shelf life, a quick staling, a dry mouthfeel, and a dissatisfactory taste. Although numerous attempts have been made to improve the quality of gluten-free bread, studies are still necessary to optimize recipes and processes.

Sourdough in GF bread

One of the main trends on the market is the use of sourdough especially for bread because it has been demonstrated the fact that this one has a positive sensory, nutritional, texture, and shelf life features influence of baked goods (De Vuyst et al., 2009; Gobbetti et al., 2014).

Overall, the sourdough fermentation has opened new ways in improving the quality and acceptability of gluten-free bread.

During sourdough fermentation, acid occurs, which enhances the swelling of polysaccharides that could partially replace gluten and improve the gluten-free bread structure (Moroni et al., 2009).

According to Coda et al. (2010), lactic acid bacteria are very important because this ferments gluten-free flours; the result is the production of functional breads enriched with bioactive compounds. *Lactobacillus plantarum* and *Lactococcus lactis* subsp. *lactis* were selected to synthesize γ-aminobutyric acid (GABA), through sourdough fermentation of wheat, rye, spelt, oat, buckwheat, rice, amaranth, millet, chickpea, soy and quinoa flour. *L. plantarum* C48 produced the highest amount of GABA with buckwheat and quinoa fermentation.

It has been revealed that using *Lactococcus lactis* subsp. *lactis* PU1 the best results were for amaranth and chickpea flour (Arendt et al., 2011). Using the same pattern, Wolter et al. (2014) incorporate *Weissella calbaria* MG1 starter sourdough to buckwheat, sorghum and teff flour; this softened the batter, which in turn influenced the rheology and baking properties.

Lynch et al. (2014) used *Lactobacillus amylovorous* DSM19280 which is known for antifungal activity to produce quinoa sourdough bread. By adding sourdough fermented by this organism, the mold free shelf life was increased for 4 days compared with gluten-free normal bread, without sourdough, which showed visible mold after only 2 days. Acid production leads to delayed mold growth.

The bread quality in terms of mechanical strength and loaf volume improved and the staling rate decreased (Axel et al., 2015). When sourdough fermented with *Lactobacillus fermentum* was added to gluten-free batter, the glycemic index decreased from 68 to 54 g/ 100 g. It was also observed that the bread texture and volume improved, and the staling was also considerably delayed (Novotni et al., 2012).

Gluten-free cereals in gluten-free biscuits

Although rice is one of the most used cereals in the production of gluten-free biscuits/cookies, researchers tried to add different ingredients for new formulation. Tavares et al. (2016) incorporate co-products generated during industrial processing; they added toasted rice bran, broken rice flour and soybean okra in the original formulation. Because of this addition, biscuits/cookies had a lighter colour, a lower water activity and a smaller specific volume compared to commercially available samples.

A mix of brown rice flour, soya flour, maize and potato starch was studied by Scober et al. (2003). The result was comparable with wheat biscuits/cookies. However, other mixtures such as brown rice flour, potatoes starch, buckwheat flour, millet flakes or brown rice flour, soya flour, maize starch, potato starch, millet flakes did not show positive results.

Oats in GF products

Oats consumption is considered safe for the majority of celiac people, but this fact is still under research by the scientific community (Comino et al., 2015).

Oats could possibly have a post-harvest contamination with gluten which can appear from the other cereals. It has been demonstrated that higher replacement levels or a total substitution of oat flour by oat bran in cookie formulations, affect negatively the acceptability by the consumers (Duță & Culețu, 2015).

Pîrvulescu et al. (2014) studied the differences between normal flours and flours obtained from germinated oats. The result shows a lower content of glucose present in the flour made from germinated oats. This demonstrates the fact that germinated flours can be used in hypoglucidic diets. It is an important thing to know because most of celiac people also suffer from diabetes.

Pseudo-cereals in GF products

Buckwheat is one of the most researched pseudo-cereals for GF biscuit formulation. During thermal treatments, buckwheat flour can maintain its antioxidant capacity (Sakac et al., 2011).

Sakač et al. (2015) replaced rice flour with buckwheat flour (10, 20 and 30% proportion) and observed the fact that the final products had high mineral availability, antioxidant potential (DPPH assay), phenolic level and raised rutin content.

Besides this, Torbica et al. (2012), demonstrated that a mixture of rice and buckwheat flour represents a successfully formulation for GF cereal-based products, like biscuits. Their products presented a good shape, appearance and a pleasant flavor. Another study revealed that buckwheat-based bakery products have a significant antioxidant content (Sedej et al., 2011). GF crackers were made with buckwheat flour and a higher antioxidant content was found, compared to the control crackers with wheat flour.

Another highly nutritious pseudo-cereal, with excellent protein quality and rich in minerals and vitamins is quinoa. Although quinoa is highly nutritious, it presents a major drawback in bakery industry because of the lack of gluten (Thejasri et al., 2017). However, there are many studies based on quinoa flour formulations. Based on an experimental design procedure, Brito et al. (2015) compared mixtures based on quinoa flour, quinoa flakes and maize starch in biscuit formulations. The result was that quinoa flour and flakes formulation have a higher content of proteins, sugars and phenolic compounds. Quinoa flakes and maize starch had a positive effect on the volume of the assessed biscuits.

Due to nutritional intake, amaranth could be very useful in developing products for celiac people. Chauhan et al. (2015) showed that the use of germinated amaranth flour produced acceptable amaranth GF biscuits with a good nutritional quality. Amaranth biscuits had a higher spread ratio than control wheat biscuits which is a desirable characteristic in biscuits. Inglett et al. (2014) also produced amaranth-oat biscuits in a 3:1 ratio, with different type of oat (whole oat flour, oat bran concentrates and steam cooked oat bran concentrate). Biscuits made from amaranth and whole oat flour had the most similar characteristics with the control.

Legumes in GF products

Nowadays 1.8% of the EU arable land is cultivated with legumes compared to 4.7% in 1961 so the Common Agricultural Policy required the production of vegetable proteins to increase (Roman et al., 2016).

Legumes flours are used to increase nutritionally the quality of GF products. All of them are an important source of nutrients such as proteins, complex carbohydrates, fibres, micronutrients and antioxidant compounds (Melini et al., 2017). However, Maghaydah et al. (2013) demonstrated the fact that it is not possible to make GF biscuits exclusively with legume flours. Biscuits with 100% lupine flour were not as good as biscuits in combination with maize flour, or maize starch, rice flour and maize flour with the addition of xanthan gum and

carrageenan. Giuberti et al. (2018) used legumes to increase nutritional value of biscuits. By adding alfalfa seed flour, biscuits showed an overall improvement of nutritional quality. Alfalfa biscuits recorded an acceptable score, but all rice biscuits resulted to have better sensory scores. According to Mancebo et al. (2016) another solution to improve the quality of GF biscuits could be the addition of legume proteins instead of adding legume flours to the formulation. The addition of proteins did not have a negative impact on sensory properties, and they increased dough consistency.

***Rosa damascena* in Gluten-free cookies (GFC)**

Rosaceae family contains different components such as terpenes, glycosides, flavonoids and anthocyanins. It has different properties such as: antioxidant, antimicrobial, analgesic, anticancer, anti-inflammatory, antimutagenic, antidiabetic and antidepressant. (Boskabady et al., 2011; Mahboubi, 2016).

The flour was obtained from dried and ground petals. The other ingredients were potatoes and corn starch, corn and rice flour, sodium bicarbonate, corn syrup, hydrogenated vegetable oil, fine granulated sugar and salt. Rosa flour (RF) GFC were made with 2.5-5-7.5-10% RF added (Gül & Tekeli, 2018).

GFC were sensory analysed. The score was higher for 10% RF concentration for taste but lower for the texture. The best score was recorded by 7.5% RF added GFC regarding odour, aroma and mouth feel (Gül & Tekeli, 2018).

CONCLUSIONS

Celiac disease affects approximately 1% of the world and this percentage is still growing. The only treatment for celiac people is adherence to gluten-free foods.

The most common ingredients used in developing GF products are corn and rice, but researchers permanently try to find new formulations.

Apart from rice and corn, there are other types of flours used in baking gluten-free products from cereals (sorghum), pseudo-cereals (buckwheat, quinoa, amaranth), minor cereals (teff, millet), and legumes (soybean, chickpea, lentil, pea), seeds (flax seeds, chia seeds, pumpkin seeds), nuts (almonds, hazelnuts, chestnuts, walnut, cashew nut), and tubers (arrowroot, tapioca, jicama, taro, potato).

A drawback, and probably the only one, of developing GF products which contain pseudo-cereals, legumes and seeds is that they have a higher price and are harder to find in comparison to corn and rice.

It is very hard to develop GF products because celiac people have various nutrient deficiencies. The production of gluten-free products assumes different challenges to face.

Gluten is an essential element which helps in structure building protein, necessary to formulate high quality cereal-based goods.

The lack of gluten affects the structure of the dough causing a liquid batter and several defects in baked products.

Although the addition of sourdough to gluten-free bread is not an approach at industrial level, studies have shown so far that the use of selected lactic acid bacteria improves the nutritional properties as well as increases the shelf life (with 4 days) of the breads. Sourdough also improves the volume, texture and sensory quality of the gluten-free breads.

For biscuits/cookies, gluten does not play a fundamental role as in bread or other soft products with biological leavening.

The texture of biscuits/cookies does not depend on protein/starch structure, but it depends especially on starch gelatinization and sugar.

ACKNOWLEDGEMENTS

This study was achieved through Core Program, with the support of the Ministry of Research and Innovation (MCI), contract 22N/2019, project PN 19 02 02 02 and USAMVB PhD fellowship programme.

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