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GLUTEN-FREE PRODUCTS AND POSSIBILITIES OF NEW FORMULATION FOR IMPROVING TEXTURAL AND NUTRITIONAL CHARACTERISTICS - REVIEW

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Abstract

Because 1-2% of the population suffers from celiac disease and the number increased in the last 20 years, the food industry needs to develop gluten-free products that can be consumed by people with celiac disease. The negative aspect of these products is that they are rich in carbohydrates and deficient in nutrients such as protein*, dietary fiber, vitamin B, vitamin D, folate, iron, calcium, copper, zinc, magnesium. The purpose of this paper is to assess from nutritional and textural point of view gluten-free products such as gluten-free bread, gluten-free cookies/biscuits, gluten-free muffins, gluten-free pasta, gluten-free waffles and wafer. For improving nutritional characteristics, gluten-free ingredients rich in nutrients such as rice, buckwheat, quinoa, amaranth, sorghum, oats, corn, teff, inulin, wheat starch, potato starch, milk and soy protein, legumes, chia and flax seeds, microalgae, psyllium, walnuts and almonds are described. For improving textural characteristics, the role of enzymes, microorganisms and hydrocolloids is considered. Possibilities of new formulation for these gluten-free products have been exemplified. For this review, 69 scientific articles from the Science Direct database were studied.*

Key words*: celiac disease, gluten, gluten-free diet, ingredients, products.*

INTRODUCTION

People suffering from celiac disease have to consume gluten-free products (Yılmaz & Koca, 2020), but these products are also preferred by healthy people (Sarabhai et al., 2020) influenced by celebrities who use the gluten-free diet as a way to be fit (Xhakollari et al., 2019) and for health benefits to avoid the risk of gastrointestinal diseases (Gobbetti et al., 2018) and to have benefits on digestive health, weight loss and clearer skin (Arslain et al., 2021).

Globally, 1-2% of the population suffers from celiac disease (Xhakollari et al., 2019), but the number had constantly increased over time (Xu et al., 2020; Drabinska et al., 2016) in the last 20 years (Jagelaviciute & Cizeikiene, 2020).

This resulted in a rapid expansion of the market segment and the specialized companies will be interested to make gluten-free products (Xhakollari et al., 2019).

A big challenge for the bakery companies is to obtain gluten-free bread similar to wheat bread (Zorzi et al., 2020; Gobbetti et al., 2018), with the same flavor and texture (Drabinska et al., 2016).

For the formulation of gluten-free products, raw materials have to improve sensory and nutritional characteristics.

The aim of this paper is to assess information about the gluten-free diet, gluten-free ingredients and products and the possibilities of new formulation that can be used to improve textural and nutritional characteristics.

MATERIALS AND METHODS

The materials used are represented by scientific publications from around the world.

The methods used are in according with the paper purpose, respectively: to assess from nutritional and textural point of view gluten-free products such as gluten-free bread, gluten-free cookies/biscuits, gluten-free muffins, gluten-free pasta, gluten-free waffles and wafer.

RESULTS AND DISCUSSIONS

CELIAC DISEASE AND ITS IMPLICATIONS

Celiac disease is a chronic autoimmune disease characterized by villous atrophy of the small intestine (Atsawarungruangkit et al., 2020; Mohammadi et al., 2014), determined by gluten ingestion (Caio et al., 2020) with a permanent intolerance (De Arcangelis et al., 2020).

Gluten is the main structural protein from some cereals, it has a high proline content and resistance in gastrointestinal tract to proteolytic degradation because the specific enzymes do not have post-proline cleavage activity (Olojede et al., 2020).

The protein fractions are gliadin and glutenin (Arendt & Dal Bello, 2008). Gliadin influences the viscosity and glutenin influences the elasticity (Drabinska et al., 2016), therefore gluten is defined as a viscoelastic mass (Nutter et al., 2017). The absence of gluten affects the mechanical properties of the dough processing (Moreira et al., 2013).

Gluten forms the strong protein network (Liu et al., 2018) with influence on the rheological properties of dough (Andersson et al., 2011) and bread, such as viscoelasticity, consistency, mixing tolerance, tensile strength (Lazaridou et al., 2007; Zorzi et al., 2020), gas retention capacity comprising fiber fragments and starch granules (Arendt & Dal Bello, 2008), being responsible for the total acceptability of the bread (Moghaddam et al., 2020) and having an impact on the quality of wheat products (Li et al., 2019).

It is difficult to assess the tolerated amount of gluten by people without developing deleterious effects, but it is considered that less than 10 mg of gluten / day intake do not cause problems (Gobbetti et al., 2018).

The ingestion of gluten depending of time and dose (Dotsenko et al., 2020) is related to the intestinal mucosa damage and malabsorption of several important nutrients (Lazaridou et al., 2007). Sarabhai et al. (2020) say that celiac disease is an autoimmune enteropathy with a long-term sensitivity to gluten.

The symptoms are weight gain or weight loss, steatorrhea, anemia, abdominal discomfort, severe diarrhea and fatigue (Arendt & Dal Bello, 2008; Olojede et al., 2020).

Celiac disease is most common in pediatric age but it can be developed at any age (Gobbetti et al., 2018).

Due to the increased number of patients with this disease it is necessary to avoid gluten throughout life and the processed foods based on wheat (Aoki et al., 2020). A dietary assessment tool can be helpful for this purpose (Atsawarungruangkit et al., 2020).

The commune raw materials containing gluten are: wheat, oats, rye and barley (Arendt & Dal Bello, 2008; Olawoye et al., 2020; Drabinska et al., 2016). Gluten is responsible for dough processing and textural characteristics of bread products. The finished products to avoid by people with celiac disease are: bread, pastries and other food products containing wheat flour. Salad dressings, cream sauces, hamburgers, processed cheese and mixtures of dried or canned soups can also contain hidden ingredients as by-products or processed foods containing wheat and gluten-derivatives as fillers agents and thickeners.

Due to the gluten sensitivity and prevalence of celiac disease, it is necessary to avoid it (Andersson et al., 2011), by consuming gluten-free products (Bender & Schonlechner, 2020).

GLUTEN-FREE DIET

The gluten-free diet is the only available solution (Caio et al., 2020), facilitating mucosal recovery (Mohammadi et al., 2014; Lazaridou et al., 2007). The elimination of gluten-containing foods helps to the protection of the intestinal mucosa, the disappearance of inflammation and normal absorption of nutrients (De Arcangelis et al., 2020).

A gluten-free diet has a positive impact on autism, intolerance to eggs, soy, wheat and milk (Xhakollari et al., 2019). In order to follow a gluten-free diet is necessary to know information about ingredients and food preparation. A qualified dietitian can monitor these diets (Atsawarungruangkit et al., 2020).

Eliminating gluten from the diet, most of the patients have the feeling of life quality limitation as a sacrifice (Caio et al., 2020).

Data on the nutritional balance demonstrate controversy (Polo et al., 2020) due to its low content of protein, dietary fiber and essential fatty acids (Moreira et al., 2013) and may

present sensory, economic and social difficulties (Gobbetti et al., 2018).
The products are characterized by a low intake of protein, dietary fiber, vitamins, and minerals: vitamin B (thiamine, riboflavin, niacin), vitamin D, folate, iron, calcium, copper, zinc, magnesium and a high intake of carbohydrates, calories, fat and sodium (Arslain et al., 2021; Jagelaviciute & Cizeikiene, 2020). The price for gluten-free cereals and bakery products compared to conventional products are + 205% and + 267% higher (Xhakollari et al., 2019).
In order to improve the nutritional properties of these products is necessary to fortify them with ingredients rich in micronutrients (legumes and pseudocereals) (Polo et al., 2020).

INGREDIENTS FOR OBTAINING GLUTEN-FREE PRODUCTS

Gluten-free cereals can be used for nutritional and health benefits in the manufacture of high-quality foods necessary for patients with celiac disease (Ogunsakin et al., 2015).
To obtain gluten-free products, cereal flour (rice, sorghum, corn, teff, millet), legume flour (chickpeas, lentils, dried beans, peas, soybeans), pseudocereals flour (amaranth, quinoa, buckwheat) (Polo et al., 2020), oats, chia seeds, alfalfa seed flour, root and tuber flour (potato) and bean flour can be used (Liu et al., 2018; Olawoye et al., 2020).
Researchers have used the addition of non-gluten proteins, starch, hydrocolloids, emulsifiers and enzymes to improve the quality of gluten-free products (Sarabhai et al., 2020).

RAW MATERIALS

Rice has in albumin the highest content of lysine while in globulin there is a major content of sulfur amino acids (Almeida Sá et al., 2020). Lysine could provide added value to some foods (Nutter et al., 2017). *Rice* flour is suitable for gluten-free bread (Aoki et al., 2020) with a low level of prolamine. Formulations for *rice* flour bread have been used carboxymethylcellulose (CMC) and hydroxypropylmethylcellulose (HPMC) (Gallagher et al., 2002). *Rice* flour can be formulated with starch and protein from cereals, pseudocereals and legumes because they provide optimal dough properties and bakery product quality (Xu et al., 2020).
Buckwheat can be useful in treating chronic diseases such as diabetes, hypertension and other cardiovascular diseases (Wijngaard and Arendt, 2006). *Buckwheat* can be used to obtain high quality gluten-free bread in combination with xanthan gum. The health benefits have been observed because of their high content of dietary fibers such as β-glucan, functional protein with a well-balanced amino acid profile, essential fatty acids, vitamins, antioxidant phytochemicals, including high phenolic compounds and sterols (Flander, 2007; Gangopadhyay et al., 2015) and minerals, (Ahmed et al., 2014; Krkoskova & Mrazova, 2005).
Quinoa is an excellent source of energy and nutrients, being rich in proteins, B vitamins, minerals (Jagelaviciute & Cizeikiene, 2020) and fibers (Ceyhun Sezgin & Sanlier, 2019) and it has a high content of saponins, conferring toxicity and bitter taste at a high concentration. Also, *quinoa* seeds present anti-nutritional factors as tannins, phytic acid, oxalates and trypsin inhibitors (Filho et al., 2017). The content of methionine and lysine is improved with a reduced addition of *quinoa* compared to corn protein. *Quinoa* seeds also bring an increased intake of energy and nutrients (Arendt & Dal Bello, 2008). It has a high mineral content and a higher amount of folic acid. The partial replacement of corn and rice flours with *quinoa* flour can increase the specific volume of the product (Gobbetti et al., 2018).
Amaranth is rich in macronutrients (12-22% proteins and 6-13% lipids), dietary fibre (9-14%), minerals, vitamins, polyphenols and phytosterols. It has high lysine and methionine content (Grundy et al., 2020). *Amaranth* can have positive health effects to the reduction of cardiovascular disease risks. Replacing 10% of the corn starch with *amaranth* flour can increase protein and fiber content of gluten-free breads (Gambus et al., 2002).
Sorghum has a high content of phytosterols, phenolic acids, tannins and anthocyanins. Several studies have reported obtaining of bread with carboxymethyl cellulose, sorghum flour, xanthan gum, skimmed powder milk and eggs (Cauvain, 1998) to improve the quality of gluten-free bread (Arendt & Dal Bello, 2008). Sorghum proteins have a lower nutritional quality compared to milk and legume proteins

(Olojede et al., 2020). Combining *sorghum* flour with potato, rice, cassava starch or corn, studies have shown that the acceptability of the bread improved (Moghaddam et al., 2020).

Oat contains phytates, phenolic compounds, vitamins and minerals and it has lower proline content. β-glucans present beneficial effects on diabetes, reduce the risk of coronary heart disease and serum cholesterol (Oomah and Mazza, 1999). A concern for people with celiac disease is that oat could be contaminated with gluten cereals such as rye, wheat or barley during grain harvesting, transport, storage and processing (Xu et al., 2020).

Corn is an important source of fats and carbohydrates, but *corn* flour is not rich in tryptophan, lysine, omega 3 fatty acids, calcium, phosphorus and iron (Yılmaz & Koca, 2020). *Corn* flour is formed from endosperm with 75-87% starch and 6-8% protein (Shukla and Cheryan, 2001). As binding agents for replacing gluten can be used: guar gum, xanthan and acacia gum with an increased volume of bread. *Corn* flour can be used to obtain tortillas, pancake and bread premixes, cereals and chips (Arendt & Dal Bello, 2008).

Teff, an ancient grain, presents 11% protein, 3% fat, 80% carbohydrate, essential amino acids, especially lysine, the amino acid that is deficient in grain foods, fiber, calcium, iron, potassium. *Teff* flour can be mixed with millet and sorghum to obtain a flat bread with an improved nutritional value (Villanueva et al., 2021), biscuits, waffles, muffins, cakes, stews, soups and puddings (Ketema, 1993).

Inulin is classified as a dietary fiber and it is an indigestible fructooligosaccharide. Studies have shown that the addition of fiber-rich ingredients improve texture, emulsifying, thickening, gelling, stabilizing and prebiotic properties. An addition of 8% *inulin* in a formulation with wheat starch improved the quality of gluten-free bread (Gallagher et al., 2002).

Wheat starch is a carbohydrate the most abundant in wheat, wheat flour and many foods. Research has shown that among wheat starch and additives formulations, the best quality breads were produced with the addition of xanthan gum. (Kulp et al., 1974).

Potato starch has high water binding capacity, swelling power and frost-thaw stability (Madsen and Christensen, 1996).

Milk proteins have functional properties similar to gluten, good swelling properties, nutritional and functional benefits including the improve of flavor and texture (Gallagher et al., 2004).

Surimi is a concentrate of myofibrillar proteins. Studies have been performed to obtain gluten-free bread based on rice flour, potato starch and surimi (as a structural enhancer and protein substitute) (Gormley et al., 2003).

Soy protein is rich in high-quality protein (38-55%) and essential amino-acid, carbohydrates (27.1%) and oil (20.6%) (Osundahunsi et al., 2007). It is a cheap legume crop cultivated in tropical regions. Studies have been conducted for the formulation of gluten-free bread based on wheat starch with 20, 30 and 40% *soy protein* isolate (Arendt & Dal Bello, 2008).

Legumes are sources of energy, protein, carbohydrates, fiber, vitamins and minerals. They are characterized by high lysine content and a limited source of methionine, cysteine and tryptophan. *Peas* and its protein isolates provide sulphur amino acids (Nutter et al., 2017). *Chickpea* are excellent sources of protein (23-27%) compared to other leguminous plants and they are important sources of the essential nutrients (Olojede et al., 2020). *Lupine* isolates meet the essential requirements of amino acids (Nutter et al., 2017).

Chia seeds contain carotenoids, omega-3 fatty acids, fiber, vitamin E (Jagelaviciute & Cizeikiene, 2020), proteins, minerals and phyto-chemicals such as phenolic compounds (Silva et al., 2017). Studies have shown that a combination of *chia seeds* and hydrocolloids modified significantly the rheological properties of doughs (Moreira et al., 2013). *Chia seed* is considered the highest botanical source of alpha linolenic acid (ALA) omega 3 (n-3). Chia, hemp and quinoa flour can be used for fermentation with *Lactobacillus sanfranciscensis* for the production of gluten-free bread (Jagelaviciute & Cizeikiene, 2020).

Flax seeds have low levels of trans fatty acids (especially n-3α-linolenic acid) (Gobbetti et al., 2018) and are a source of protein, fiber, phenolic compounds (Nutter et al., 2017) and active components (Oomah, 2010).

Microalgae are natural sources of proteins, essential amino acids, polyunsaturated fatty acids, vitamins, minerals, enzymes, carotenoids and fiber. Studies have used *Chlorella* *sorokiniana*, to obtained bread enriched with proteins, polyunsaturated fatty acids and carotenoids. The addition of *microalgae* did not show an effect on the volume and texture of the bread, but it can affect its sensorial characteristics such as the color that is greenish (Diprat et al., 2020).

Psyllium can improve volume, texture, structure, acceptance, appearance, shelf life and it presents fiber enrichment and lowering glycemic index (Santos et al., 2020). The consumption of *psyllium* can reduce the risks of metabolic conditions by improving glucose levels, insulin response and lipid profile (McRorie, 2015).

Walnuts and almonds have a high content of lipids, including fatty acids (Nutter et al., 2017) and they are rich in alpha-linolenic acid (ALA), melatonin, magnesium and antioxidants (Ma et. al., 2010). They can predict lower blood pressure, lower serum total cholesterol and low-density lipoprotein (LDL) cholesterol, greater endothelial function (i.e., flow mediated dilation), and lower risk of developing type 2 diabetes.

ENZYMES

Transglutaminases are enzymes able to bind proteins of different origins: soy proteins and wheat proteins, proteins from eggs and meat, casein and albumin from milk, improving the quality depending on the enzymatic concentration (Bender & Schonlechner, 2020) and protein source (Kuraishi et al., 1996) and they can contribute to the creation of a protein network similar to gluten (Gobbetti et al., 2018).

Oxidases as glucose oxidase and laccase can contribute to the creation of a protein network (Gobbetti et al., 2018) and the dough fermentation, stability and processing can be improved (Bender & Schonlechner, 2020). Oxidases can intensify crust colour, develop finer, crumb structure and can increase the shelf life. The enzymes are denatured during baking process and they cannot be identified in the final product (Sarabhai et al., 2020).

MICROORGANISMS

Yeast and lactic acid bacteria synthesize metabolites such as vitamins and the use of sourdough containing them is appropriate to make gluten-free bread by improving processing conditions and product quality (Olojede et al., 2020).

Yeast are rich in folate. These determine a fast conversion of sugars into alcohol and CO_2 but the main acidification of the dough is made by lactic acid and acetic acid generated by lactic acid bacteria. The ratio of lactic acid to acetic acid is necessary for aroma, texture and shelf life of the bread, but also by-products such as CO_2, ethanol, fatty acids, hydrogen peroxide, diacetyl, contributes to conservation. Lactic acid bacteria can degrade phitic acid at pH 5-5.5 (Jagelaviciute & Cizeikiene, 2020).

Lactobacillus reuteri produces vitamin B12. *Lactobacillus plantarum* and *Lactococcus lactis* synthesize high levels of γ-aminobutyric acid. *Lactobacillus plantarum* decreases the values of pH (Moghaddam et al., 2020). *Lactobacillus plantarum, Lactobacillus fermentum and Lactobacillus paralimentarius* are used to make corn and rice products (Bender & Schonlechner, 2020).

HYDROCOLLOIDS

Hydrocolloids are substances with protein or polysaccharide structure and a high molecular weight being composed of long-chain hydrophilic molecules and can produce gels (Hoefler, 2004).

They can be obtained from plant extracts, fruits, seeds, microorganisms and seaweed. They have two basic functions in foods: they improve the texture and stabilize the product (De Arcangelis et al., 2020).

The presence of hydrocolloids which are able to bind water determines a shorter shelf life of the product.

For gluten-free products can be used hydrocolloids such as hydroxypropyl methylcellulose, pectin, cellulose, xanthan gum, locust gum and guar gum (Arendt & Dal Bello, 2008) to improve the quality (Xu et al., 2020) and water retention capacity (Li et al., 2019).

The combination of carboxymethylcellulose and hydroxypropyl methylcellulose gives to the dough viscoelastic properties (Gobbetti et al., 2018).

The combination of carboxymethylcellulose (CMC) and other gums and stabilizers improves water absorption capacity.

Xanthan increases gas retention, water absorption and dough stability (Mohammadi et al., 2014) and can improve textural properties such as chew ability and hardness of products (Yılmaz & Koca, 2020) giving the greatest effect on viscoelastic properties. The combination of xanthan and hydroxypropyl methylcellulose can be used in the rice bread making (Aoki et al., 2020), but also combinations of maize flour, rice flour, potato starch, carboxymethylcellulose (1%), hydroxypropyl methylcellulose (2.3%), guar gum (1.9%) and xanthan gum (0.6%) obtaining an increase in volume and a decrease in hardness (Mohammadi et al., 2014; Liu et al., 2018).

Studies have shown that resistance to deformation and elasticity are in the order: xanthan>carboxymethylcellulose>pectin>agarose>β-glucan. Increasing the level of hydrocolloids from 1% to 2%, except for pectin, can cause the decreasing of the bread volume (Lazaridou et al., 2007).

GLUTEN-FREE PRODUCTS

Gluten-free products are mainly made from rice flour, corn flour and starch.

Because studies have shown that many people consider difficult to find gluten-free products with a good taste, it is necessary in many cases to increase the sugar and salt content (Xhakollari et al., 2019).

Celiac disease has led to an increase of gluten-free products such as pasta and bread (Andersson et al., 2011; De Arcangelis et al., 2020), but other categories have been developed too: biscuits, pizza, waffles (Xhakollari et al., 2019).

Is very important the technology of obtaining gluten-free products and that chemical fermentation can be adopted to obtain biscuits, cookies, muffins and cakes (Xu et al., 2020).

GLUTEN-FREE BREAD

The use of sourdough is an old technique and it is increasingly used today to make bread. The sourdough is a leavening agent and a fermented mixture of water and flour with benefits to the metabolic activities of lactic acid bacteria such as proteolysis, lactic fermentation, avoidance of microbial contamination and synthesis of aromatic compounds (Di Cagno et al., 2003) having an essential role to the quality of finished products (Li et al., 2019) and improving the nutritional value, aroma, taste and shelf life of the bread (Ogunsakin et al., 2017).

It could decrease the phytate content of flours by stimulating endogenous phytase activity (Rinaldi et al., 2017).

Gluten-free bread requires an other technology compared to conventional bread because of the absence of gluten which determines liquid dough and quality defects such as poor color and crumbly texture (Arendt & Dal Bello, 2008).

Studies have shown that a fermentation of corn starch, brown rice, soy flour and buckwheat mixture with *Lactobacillus plantarum* delayed the growth of *Fusarium culmorum* (Gobbetti et al., 2018).

By using another gel, gluten-free dough can retain CO_2. Gluten-free breads have a lower quality (Mohammadi et al., 2014).

Other studies showed combinations of gluten-free flour (rice flour and corn flour), milk protein, starch, hydrocolloids being able to imitate the gluten viscoelastic properties (Lazaridou et al., 2007), but also by adding 5% inulin, the volume was increased (Drabinska et al., 2016).

To improve the quality of gluten-free bread, enzymes, hydrocolloids, unconventional heating methods and high hydrostatic pressure can be used (Bender & Schonlechner, 2020), but also the supplementation with β-glucan improving the volume, reduction in serum levels of LDL cholesterol and lower glycemic index (Andersson et al., 2011).

GLUTEN-FREE COOKIES/BISCUITS

The main ingredients to obtain biscuits include flour, water, fat, sugar and salt.

Comparing sensory acceptability and texture, gluten-free cookies are considered inferior to wheat-based cookies.

Studies for people with celiac disease have shown that rice cookies with 7.5% soy protein isolate or whey protein concentrate have been safe. To maintain texture and reduce calories, artificial sweeteners such as stevia, neotame, allulose, aspartame-acesulfame salt, advantame, cyclamate, neohesperidin and others are potential alternatives (Gongora Salazar et al., 2018).

The addition of hydrocolloids improves the rheological properties of the dough (Xu et al., 2020).

The inulin can be used as a source of dietary fiber (Drabinska et al., 2016). Modifying starch through chemical, physical or enzymatic methods, the nutritional improvement can be achieved (Olawoye et al., 2020).

Brown rice and apple pomace can be used as functional ingredients, the obtained biscuits being acceptable in terms of sensory. Biscuits with 9% apple pomace have antioxidant properties, a high content of dietary fiber and polyphenols and are rich in minerals such as chlorine, phosphorus potassium, and sulfur (Mir et al., 2017).

GLUTEN-FREE MUFFINS

The "bakery products" category includes also the muffins (Belorio & Gómez, 2020). Muffins are made from wheat flour, egg, oil, milk and sugar.

Gluten-free muffins can be developed using gluten-free flours such as millet, rice, buckwheat and chickpeas.

For the development of muffins, studies have shown combinations of flours, for example: rice flour and quinoa mixture; rice flour, soy flour and corn starch mixture; rice flour and buckwheat flour mixture; rice flour and green banana flour (50/50) mixture; buckwheat flour and corn starch mixture.

Green banana flour can improve the aroma, taste, volume, texture, general acceptability and the mineral content of the muffins.

To improve the quality of rice muffins, proteins (pea protein isolate, soy protein isolate, egg white protein and casein), enzymes and gums can be used. The protein isolates improve the elasticity, specific volume and cohesion (Xu et al., 2020) and the xanthan gum (0.5 and 1%) increase the viscoelasticity of the dough.

GLUTEN-FREE PASTA

To achieve balanced formulations, excellent nutritional and quality properties, rice flour as major ingredient (Ribeiro et al., 2018; Bouasla and Wojtowicz, 2019), corn flour, buckwheat flour, emulsifiers and stabilizers (carob flour and guar, fatty acid monoglycerides, propyleneglycol alginate) can be used. Starch plays a structuring role.

Buckwheat flour led to pasta with a high content of dietary fiber and protein (De Arcangelis et al., 2020).

The quality of the pasta during cooking is influenced by the protein content which is structural ingredients with role in the structure, sensory and textural properties of pasta. Proteins such as egg whites, dairy ingredients and protein isolates can be used. Some studies have shown that whey proteins determine a strong starch-protein network (Ungureanu-Iuga et al., 2020).

Studies have shown that pasta enriched with 5% inulin had a good quality (Drabinska et al., 2016).

WAFFLES AND WAFER

Gluten-free waffles can be obtained using rice, buckwheat and corn flour and the technology should be adapted for patients with celiac disease.

The moisture content for corn and rice flour dough should be reduced compared to the moisture content of wheat flour dough (Nascimento et al., 2013; Paucean et al., 2016). For the dough with buckwheat flour and to obtain high quality waffles, the moisture content should be increased. This dough has maximum viscosity and density, while the rice flour dough has these parameters at a minimum.

Wafer sheets from buckwheat and corn flour have specific flavor and color characteristics. Wafer sheets from buckwheat flour have a higher amount of protein compared to wafer sheets from rice and corn flour (Dorohovych et al., 2018).

CONCLUSIONS

People with celiac disease should avoid gluten-containing ingredients such as: wheat, oats, rye and barley (Drabinska et al., 2016). They should also avoid gluten-containing products such as bread, pastries, by-products or processed foods (Andersson et al., 2011).

To obtain gluten-free products with balanced nutritional quality and sensory acceptability (Xu et al., 2020) the ingredients play an important role (De Arcangelis et al., 2020).

Gluten-free products are poor in nutrients such as protein, dietary fiber, vitamins, and minerals: vitamin B, vitamin D, folate, iron, calcium, copper, zinc, magnesium (Arslain et al., 2021; Jagelaviciute & Cizeikiene, 2020) and they need to be nutritionally improved, by using ingredients rich in these micronutrients such as legumes and pseudocereals (Polo et al., 2020).

Rice flour can be formulated with starch, cereals, pseudocereals and legumes due to their properties for dough and bakery product quality (Xu et al., 2020). *Buckwheat* can be used in combination with xanthan gum to obtain high quality gluten-free bread. Q*uinoa* flour can be used in combination with corn and rice flour to increase the specific volume of the product (Gobbetti et al., 2018). *Amaranth* flour can be used in combination with corn starch to increase protein and fiber content of gluten-free breads (Gambus et al., 2002). *Sorghum* flour can be used in combination with xanthan gum, carboxymethyl cellulose, skimmed powder milk and eggs (Cauvain, 1998) to improve the quality of gluten-free bread (Arendt & Dal Bello, 2008). *Corn* flour can be used in combination with guar gum, xanthan and acacia gum with an increased volume of bread (Arendt & Dal Bello, 2008). *Teff* flour can be used in combination with millet and sorghum to obtain a flat bread with an improved nutritional value (Villanueva et al., 2021), biscuits, waffles, muffins, cakes, stews, soups and puddings (Ketema, 1993). *Inulin* can be used in combination with wheat starch improving the quality of gluten-free bread (Gallagher et al., 2002). Wheat starch can be used in combination with xanthan gum (Kulp et al., 1974). *Soy protein isolate* can be used in combination with wheat starch (Arendt & Dal Bello, 2008). Legumes such as *peas*, *chickpea* and *lupine* isolates are used to improve the quality of gluten-free products. *Chia seeds*, hemp and quinoa can be used for fermentation with *Lactobacillus sanfranciscensis* (Jagelaviciute & Cizeikiene, 2020).

Transglutaminases can contribute to the creation of a protein network similar to gluten (Gobbetti et al., 2018). Oxidases can increase the shelf life. Yeast can improve the processing conditions and product quality (Olojede et al., 2020). *Lactobacillus plantarum*, *Lactobacillus fermentum* and *Lactobacillus paralimentarius* can be used to make corn and rice products (Bender & Schonlechner, 2020).

Hydrocolloids such as hydroxypropyl methylcellulose, pectin, cellulose, xanthan gum, locust gum and guar gum (Arendt & Dal Bello, 2008) can improve the quality (Xu et al., 2020) and water retention capacity (Li et al., 2019) of gluten-free products.

With the ingredients mentioned above, gluten-free products such as gluten-free bread, gluten-free cookies/biscuits, gluten-free muffins, gluten-free pasta, waffles and wafer can be obtained but these products may require a different technology.

In conclusion, it is necessary that the ingredients should be carefully selected so that the resulting products are improved from a textural and nutritional point of view.

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