Trends in Food Science & Technology 81 (2018) 203–212

Contents lists available at ScienceDirect

Trends in Food Science & Technology

journal homepage: www.elsevier.com/locate/tifs

Review

Focus on gluten free biscuits: Ingredients and issues

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A R T I C L E I N F O

Keywords:
Biscuits
Flours
Gluten free
Glycemic index
Quality

A B S T R A C T

Background: Around 1% of world population is affected by celiac disease. Celiacs are constrained to follow a strict gluten free (GF) diet. Often their diet is unbalanced and lacks in many nutrients. In recent years, some breakthroughs have been made but there is still the need to provide better quality products to celiac people. Biscuits represent a good vehicle to distribute nutrients to celiac patients, because they are a convenient food appreciated by all groups of population. In addition, it is easier to produce gluten free biscuits than gluten free breads. Compared to bread, gluten plays a minor role in biscuits so a wider variety of flours might be employed.
Scope and approach: This paper focuses on the possibility to use alternative flours to rice and starches flours which may be employed in GF biscuits production. Furthermore, a discussion about technological, sensory and nutritional issues has been carried out. Moreover, to evaluate the composition of commercial GF biscuits, the frequency of occurrence of ingredients on the label of 282 biscuits present on Italian market is included as case study.
Key findings and conclusions: Many research showed that it is possible to formulate acceptable GF biscuits using alternative flours from cereals, pseudocereals and legumes, that may also enhance the nutritional quality, the antioxidant activity and the glycemic index of the biscuits. Malting, fermenting and germination can improve the overall quality of biscuits without affecting negatively technological properties. In Italian gluten free biscuits, maize starch and rice flour are the most frequent ingredients whereas alternative flours are still little employed.

1. Introduction

Celiac disease (CD) is an immune-mediated systemic disorder. It is a permanent intolerance to ingested gluten that damages the small intestine by inducing villous atrophy. CD is a global health problem with approximately 1% of the world population being affected (Fasano & Catassi, 2012; Leonard, Sapone, Catassi, & Fasano, 2017). Prolamins are the gluten components responsible for the immune mediated response. They are found in specific cereals: wheat, rye, barely, some cultivars of oats and their derivatives. CD is not the only disease related to gluten ingestion. In fact, gluten also causes other pathologies grouped under the term "gluten-related disorders": non-celiac gluten sensitivity, dermatitis herpetiformis, gluten ataxia and wheat allergy (Foschia, Horstmann, Arendt, & Zannini, 2016). To date, the only therapy to contrast CD and gluten related disorders is a strict adherence to a GF diet (or wheat free for wheat allergy). A GF diet consists in the consumption of naturally occurring GF foods (GF cereals, pseudocereals, fruits, vegetables, pulses, meats) and specially manufactured GF products, in which wheat flour is replaced by GF flours.

Cereals are the staple food that are exploited all over the globe for wide variety of eatable formulations. Cereals and baked products provide large amount of energy and nutrients in humans through diet. Hence, it is important to find valid GF alternatives in order to feed celiacs. In a comparison between the cereal-based products consumption of celiacs and a control population, Valitutti et al. (2017) pointed out that the consumption of biscuits and crackers is significantly higher in the CD group, whereas bread consumption is significantly higher in the control group. Biscuits seem to be an important part of celiacs' diet. It seems that people affected by CD rely more on biscuits and crackers as carbohydrate sources.

There are different challenges to face in the production of GF bakery products. First of all, gluten is responsible for different important functional characteristics and it is a big task to find ingredients able to mimic gluten and develop sensory acceptable baked GF foods. Moreover, the nutritional intake given by GF products must also be considered. Frequently, the diet of celiacs is unbalanced with high intake of saturated fatty acids and sugars and lacking in different nutrients such as dietary fibres, iron, zinc, magnesium, calcium, B12 vitamin and folate (Jnawali, Kumar, & Tanwar, 2016; Naqash, Gani, Gani, & Masoodi, 2017; Vici, Belli, Biondi, & Polzonetti, 2016).

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https://doi.org/10.1016/j.tifs.2018.09.006
Received 21 March 2018; Received in revised form 4 September 2018; Accepted 5 September 2018
Available online 07 September 2018

Furthermore, GF products often present a high glycemic index (GI) due to their starch-based composition. An high GI represents a problem for subjects affected by metabolic disorders, such as obesity and diabetes. Biscuits are based on flour, sugar, fats and on some minor ingredients. Starches, rice and maize flour are mainly employed in the production of GF biscuits. The aim of many researchers and R&D departments is to use alterative flours that could provide GF biscuits with a better nutritional quality, functional properties and sensory quality. However, in the production of biscuits, the formation of gluten network is not fundamental. Therefore, it is easier to replace wheat flour with GF ingredients in biscuit manufacturing than in the production of bread and pasta.

This review is a summary of GF biscuit research during the last 15 years. In particular, it is focused on alternatives to commonly used flours in the production GF biscuits, their functional characteristics, nutritional quality, and effect on dough, GI, final products and on consumers' acceptance. Moreover, the composition of GF biscuits available on the Italian market has been considered. An analysis of ingredients' lists has been made to find the ongoing trend of utilization of ingredients and additives too.

2. Gluten free biscuits issues

2.1. Gluten role in GF biscuits production

In the production of GF food there are different challenges to face. Gluten is an essential structure-building protein, which is necessary to formulate high quality cereal-based goods (Gallagher, Gormley, & Arendt, 2004). It plays a fundamental role in baked products, the gluten network holds the carbon dioxide produced during proofing. Consequently, the lack of gluten network makes it very difficult to obtain an acceptable texture and sufficient volume in GF bread (Drabińska, Zieliński, & Krupa-Kozak, 2016). The removal of gluten impairs the structure of the dough, causing a liquid batter and also several defects in baked products (Gallagher et al., 2004). The development of the gluten network is essential for pasta, since it affects texture and cooking quality, preventing starch swelling during cooking. The gluten network is important also in bread and other soft products with biological leavening, whereas in biscuits gluten does not play a fundamental role. The gluten network has to be only slightly developed in order to obtain a cohesive but not too elastic dough (Schober, O'Brien, McCarthy, Darnedde, & Arendt, 2003). Cohesiveness is necessary in order to have a dough which stands together during the whole process; the right degree of elasticity is necessary to obtain a clean cut during the molding phase. However, the gluten network development in biscuits is limited due to the high fat and sugar content. The texture of biscuits does not depend on protein/starch structure, but primarily on starch gelatinization and super cooled sugars (Dapčević Hadnadev, Torbica, & Hadnadev, 2013; Thejasri, Hymavathi, & Roberts, 2017). In particular, the gluten network is slightly developed in short dough biscuits in which there are high proportions of fat and sugar and the mixing phase is very short, on the contrary, the gluten network is more developed in hard sweet and semi sweet biscuits. Gluten network does not develop in biscuits from liquid batter.

Unlike in bread making, the influence of gluten on the quality of biscuit dough is difficult to define but it is known that gluten gives structure to the biscuit and holds other ingredients such as sugar, shortenings and water. Biscuits are the easiest product to formulate without gluten. In fact, it plays a secondary role in their production and end-product quality (Engleson & Atwell, 2008). Despite that, it has been seen that lack of gluten often gives biscuits of lower quality, both in terms of technological properties and sensory quality. It also works as binding agent otherwise, hydrocolloids should be used as an alternative to get successive gluten free formulations. Moreover, gluten gives the possibility to laminate and mould the biscuit in order to obtain the shape (Misra & Tiwari, 2014). In order to obtain a product comparable to conventional one, it is important to combine the right raw materials to simulate the behavior of the wheat flour and to replace wheat flour and its components (in particular starch and proteins). GF biscuits have the potential to provide essential nutrients in the diet of celiac patients because a wider range of ingredients can be employed. Mixtures of flours and additives are often used to reach an optimal result.

2.2. Nutritional quality and sensory acceptance of gluten free biscuits

Celiac patients often have to deal with an unbalanced diet, since their diet is often richer in carbohydrates but lacking in other macromolecules and in essential nutrients needed to have normal metabolism (Jnawali et al., 2016; Naqash et al., 2017; Vici et al., 2016). It is not easy for celiacs to find suitable meals outside home, they supply their diet with consistent amounts of packaged GF products, such as snacks and biscuits. This situation represents a serious risk for the attainment of a balanced diet. In fact, an increased protein and lipid consumption and fibre deficiency in people with CD has been pointed out (Caponio, Summo, Clodoveo, & Pasqualone, 2008; Stantiall & Serventi, 2017). For example, maize is often part of celiac people's diet. It gives a high energy intake but its proteins have a low biological value (low levels of lysine and tryptophan) and it lacks in many essential vitamins.

Thus to cope-up with the daily nutritional needs of body besides energy requirement, a combination of value added ingredients is needed.

Rybicka and Gliszczyńska-Świgło (2017) studied the mineral composition of different GF products, finding a high variability. The content of minerals was generally higher in GF products from buckwheat, millet, chickpea, oats, amaranth teff and quinoa than in products made with widespreaded raw materials like rice, maize, potato and GF wheat starch. In order to improve nutritional quality of sorghum, pearl millet and soy based biscuits, Omoba, Taylor, and de Kock (2015) added sourdough to the formulation. They obtained a slight increase in phenolic content and a reduction of phytate level, whereas a significantly higher antioxidant activity compared to control. The new formulation had a strong influence on sensory characteristics, with an increased sour taste, aroma and fermented flavour.

GF baked products are characterized by a reduced sensory quality compared to their gluten-containing counterparts (Drabińska et al., 2016). Mazzeo et al. (2014) evaluated visual and taste preferences of some gluten-free biscuits, in a group of celiac children. Results showed that the GF biscuits do not fully satisfy the taste of CD children. The employ of non-wheat flours may lead to a decay of sensory properties of biscuits. Generally, sensory quality of biscuits is assessed evaluating texture (breaking strength, crispiness and firmness), appearance (shape, uniformity, surface and color), flavour and taste besides overall acceptability. Because of the flours employed, gluten free biscuits may be harder and darker than gluten containing counterparts and may present a dry and sandy mouthfeel and an unpleasant appearance and taste (Schober et al., 2003). The bland and neutral taste of rice flour in GF biscuits is one of the main reasons of its large employ, but it has also been seen that the use of more tasteful flours like buckwheat flour can give a pleasant aroma to biscuits (Torbica, Hadnađev, Hadnađev, & Dokić, 2011). Refined flours are usually preferred in the production of GF biscuits. In some cases, biscuits made with wholegrain flours and/or the addition of bran result to have minor appeal. The addition of bran leads to a more grained product and, at high percentage of bran, the biscuits are darker and difficult to chew (Duta & Culetu, 2015). A higher presence of phenolic compound and ash in flours may be responsible of darker color in final products and the presence of anti nutritional compounds may give a bitter aftertaste. The incorporation of more healthy ingredients, rich in fibres and phenolic compounds results in faded sensory profile of baked biscuits.

Historically, little attention has been given to the nutritional and sensory aspect of GF products. The main rule for celiac patient was to avoid gluten containing foods. The availability of GF food products made from raw materials richer in nutrients, represents a significant improvement to provide an adequate nutrient intake to individuals with CD (de Mello Castanho Amboni, do Nascimento, Fiates, & Teixeira, 2013). Nowadays, the effort of food scientists and producers goes towards employing blends of gluten free flours to provide nutritionally enhanced biscuits with good liking scores. It must be underlined that biscuits have to be consumed in moderation because of their sugar and fat rich composition. The use of nutrient dense flour may be a way to improve their nutritional quality and to provide some important nutrients to celiacs, albeit in limited quantity.

2.3. Glycemic index of GF biscuits

GF baked products, because of their starch-rich composition, are often characterized by a high GI. Moreover, removal of gluten from bakery products can result in a higher increase of postprandial blood glucose. This is because the gluten protein network that usually surrounds the starch granules prevents an easy access of amylase to granule and inhibits the rate of starch hydrolysis in the lumen of the small intestine (Berti, Riso, Monti, & Porrini, 2004; Scazzina, Dall'Asta, Pellegrini, & Brighenti, 2015).

The association between CD and type 1 diabetes has been recognised. Patients with type 1 diabetes are a high-risk group for CD because of a shared autoimmune association and increased prevalence rates that are 4–6 times higher than those of the general population. In example, it was observed that the prevalence of CD is higher in children with type 1 diabetes mellitus than in the general pediatric population. It is important for celiacs to maintain the glycemic control while following a strict GF diet (Berti et al., 2004; DeMelo, McDonald, Saibil, Marcon, & Mahmud, 2015; Poulain, Johanet, Delcroix, Lévy-Marchal, & Tubiana-Rufi, 2007). Furthermore, a low GI diet helps to prevent and control obesity and metabolic risk factors. The use of raw materials, such as starches and refined flours which contain rapidly hydrolised starches, induces a high GI. It is desirable to employ slow digestible starches in order to have a lower increase of postprandial blood glucose. The use of naturally low GI flours, wholegrain flours from legumes and pseudocereals, native starches and the application of physical treatments such as annealing and heat-moisture can lead to a reduction of GI (Giuberti & Gallo, 2018; Rocchetti, Giuberti, & Lucini, 2018). Likewise, the addition of soluble fibres, such as guar gum, arabinoxylans, high molecular weight β-glucans or psyllium, is able to reduce the postprandial glycaemic response since they delay gastric empty (Scazzina, Siebenhandl-Ehn, & Pellegrini, 2013).

Table 1 reports the GI in vitro or in vivo of different gluten free or gluten containing biscuits. Given that the GI depends on the whole recipe, ingredient composition, processing conditions and that biscuits are rich in sugars it has been observed that some flours such as buckwheat, legumes and certain millets can reduce biscuits GI. In example, Molinari et al. (2018) measured the hydrolysis rate and calculated the expected GI of tartary buckwheat (*Fagopyrum tataricum* (L.) Gaertn) flour and biscuits. Tartary malted biscuits and flour had a medium GI, whereas rice flour and biscuits presented a high GI. The use of small concentrations of malted buckwheat flour in gluten-free biscuits can be advantageous both for increasing antioxidant activity and lowering GI. Compared to other grains, teff may also be useful in the reduction of GI. It allows to produce low GI foods, since it has lower gelatinization properties (Shumoy & Raes, 2017). Also the use of dietery fibre could be a suitable way to replace carbohydrates in GF formulation without affecting the nutritional balance. The addition of low GI ingredients in GF biscuits can be also beneficial due to the increased antioxidant activity, phenol and fibre content. When talking about GI, it must be also considered the glycemic load. The glycemic load depends on the quantity of carbohydrates present in a single portion of food. Therefore, the reduction of carbohydrate content in GF biscuits with non-digestible carbohydrates, like resistent starches, and the increase of protein content would lower the glycemic load of biscuits. Parker, Dornhost, and Frost (2000) found no significant differences between the GI in the diet of diabetic individuals with CD should not compromise glycemic control. This is in contrast with different reports which state that GF products usually present high GI. For example, Johnston, Snyder, and Smith (2017) found that GF food products significantly increase postprandial glycemia compared to conventional wheat pasta, whereas Capriles and Areas (2016) highlighted the necessity to reduce GI of starchy GF foods.

3. Gluten free flours for biscuit production

This section is a summary of research about GF biscuits of the last 15 years. It deals with different GF flours (obtained from cereals, pseudocereals, legumes) and minor ingredients that could enhance the quality of these food products. Table 2 summarizes the effects explicated by specific flours, blends or additional ingredients on dough properties, biscuits characteristic and sensory aspects. It must be remembered that many kinds of biscuits with many different recipes and different processing conditions exist. Hence, it is difficult to make a complete comparison of products in which many factors can have an influence on the product. The following text is an outline of gluten free research on biscuit and does not intend to compare biscuits obtained from different recipes and processing conditions.

Table 1
Glycemic index of conventional and GF biscuits.

Biscuit	GI	Method	References
Rice biscuits ⊗	110.2 ± 1.0	(Goñi, García-Alonso, & Saura-Calixto, 2017)	(Molinari et al., 2018)
Tartary buckwheat biscuits ⊗	62.8 ± 1.1		
Tartary malted biscuits ⊗	57.6 ± 1.0		
Maize biscuits (commercial) ⊗	37.5[a]	(ISO, 2010)	(Scazzina et al., 2015)
Bean and maize flour biscuits ⊗	61.9 ± 1.4	(Giuberti, Gallo, Cerioli, Fortunati, & Masoero, 2015)	(Sparvoli et al., 2016)
Bean and maize (1:2) ⊗	70.7 ± 0.57		
Wheat and maize (2:1)	89.9 ± 0.35		
Control rice biscuits ⊗	90	(Giuberti et al., 2015)	(Giuberti, Marti, Fortunati, & Gallo, 2017)
Rice flour and waxy rice starch ⊗	103		
Rice cookie and debranched waxy rice starch ⊗	71		
Rice flour and anneal waxy rice starch ⊗	95		
Rice flour and heat and moisture treated waxy rice starch ⊗	85		
Digestive biscuits (commercial) ⊗	83	–	(Parker et al., 2000)
Foxtail millet and wheat (45:55)	50.8 ± 27.9[a]	–	(Anju & Sarita, 2010)
Barnyard millet and wheat (45:55)	68.0 ± 60.3[a]		
Wheat	68.0 ± 52.8[a]		

[a] In vivo trials; ⊗: gluten free.

Table 2
The effect of gluten free flours and their combination on dough and biscuits properties.

Gluten free flours and additional ingredients	Flour/dough properties	Biscuit properties	Sensory aspects	References
Brown rice flour Maize starch Soya flour Potato starch	Data not reported	Biscuits comparable to wheat ones 70:10:10:10 = hardness, = thickness	Good overall acceptability	(Schober et al., 2003)
Brown rice flour Buckwheat flour Maize starch Potato starch	Data not reported	↑ hardness, ↑ thickness	Data not reported	(Schober et al., 2003)
Rice bran **Broken rice** okara	Data not reported	↑ lightness, ↓ water activity, ↓ internal & external diameter, = stability during time (compared to commercial biscuits)	Data not reported	(Tavares et al., 2016)
Oat **Oat bran**	↑ WAI values (at increasing % of oat bran)	↑ protein, fat, ash, TDF, SDF, IDF, β-glucan, ↓ starch content, ↑mineral content (in oat bran biscuits compared to oat flour), no differences in the dimensions of the starch granules in all the gluten-free formulations	All biscuits: acceptable, oat bran biscuits: lower overall acceptability	(Duta & Culetu, 2015)
Native pearl millet **Fermented pearl millet** **Malted pearl millet**	↑ WAC, OAC, swelling capacity, ↓ bulk density, (malted and fermented flour)	↑ nutritional quality for malted and fermented biscuits compared to native millet	Absence of gluten did not adversely affect biscuits acceptance, ↑ consumer acceptance for malted and fermented biscuits compared to native millet	Adebiyi, Obadina, Adebo & Kayitesi (2017)
Teff	Data not reported	↑ brittleness, ↓ toughness, ↓ thickness, ↓ spread	control and 25% teff biscuits were preferred	(Kenney et al., 2011)
Foxtail millet **Barnyard millet** **Kodo millet** (raw and germinated)	↓ peak viscosity, ↓ final viscosity & pasting temperature (at increasing % of kodo millet)	↓ diameter, ↑ thickness, (raw and germinated millets compared to wheat control) ↑ spread ratio (raw millet biscuits), ↑ phenolic content, ↑ DPPH activity, ↑ dietary fibre (germinated millets followed by raw millets and wheat flour control)	Decreasing trend for sensory score at increasing % of kodo millets, ↑ sensory scores (biscuits produced by incorporating germinated foxtail, barnyard and kodo millet in the proportion of 70:20:10)	(Sharma et al., 2016)
BuckwheatGuar gum Gum acacia Xanthan gum Gum tracanth	↑ WAC, ↑ EA, ↓ FS, = LGC (incorporation of gums).	↑ weight, ↑ fracture strength, Presence of gums: ↑ diameter of biscuits, ↑ thickness, ↓ fracture strength, ↑ softness	Control wheat biscuits had the best sensory scores. Incorporation of xanthan gum: significant improvement in color, appearance, flavor and overall acceptability	(Kaur et al., 2015)
Buckwheat Rice Carboxymethyl cellulose (CMC)	↑ soft dough, ↑ easy to handle (compared to rice dough), 20–30% replacement of rice flour with buckwheat and CMC: dough with similar behavior of wheat biscuits dough	Irregular shape and cracked surface (without CMC), ↓ fracturability, ↓ hardness (at increasing % of buckwheat)	↑ overall acceptability	(Dapčević Hadnadev et al., 2013)
Buckwheat Rice	Data not reported	↑protein content, ↑ fibre content, ↑ mineral content, ↑ total phenolic content, ↑ antioxidant activity (compared to rice control)	20–30% of buckwheat incorporation ↑ sensory scores	(Sakač et al., 2015)
Buckwheat Rice	Data not reported	Similar lightness to wheat biscuits.	Biscuits with 20–30% of buckwheat flour had the best flavour.	(Torbica et al., 2012)
QuinoaQuinoa flakes Maize starch	Data not reported	↑ lightness, ↓ hardness (biscuit with higher amount of maize starch)	good sensory acceptability, satisfactory purchase intention	(Brito et al., 2015)
Quinoa	Data not reported	↑ penetration force, ↑ withdrawal force, ↑ shear force	↑ sweetness, ↑ chewiness, No significant differences between biscuits made with wheat flour, 50:50 wheat quinoa and 100 quinoa	(Harra, Lemm, Smith, & Gee, 2011)

(*continued on next page*)

Table 2 (*continued*)

Gluten free flours and additional ingredients	Flour/dough properties	Biscuit properties	Sensory aspects	References
Amaranth (raw and germinated)	↑ WAI, ↑ OAC, (germinated flour compared to raw)	↑ spread ratio (raw amaranth flour biscuits followed by germinated amaranth flour and control wheat). ↓ hardness (raw and germinated flour). ↓ lightness	↓ sensory scores (raw and germinated compared to control – germinated better than raw)	(Chauhan et al., 2015)
Amaranth Oat bran concentrate Whole oat flour Nutrim (Oat bran concentrate steam cooked)	↑ WHC (Amaranth: nutrim and Amaranth: oat bran concentrate compared to only amaranth) ↑ WHC (Whole oat flour compared to amaranth)	↑ hardness, (only amaranth biscuit). ↓ lightness	Control wheat biscuits had the higher values (color, texture, flavour and overall) but no significant differences were found between the formulation	(Inglett, Chen, & Liu, 2015)
Bean maize	Data not reported	↑ protein content, ↑ ashes, ↑ fibre, ↓ starch content, ↓ pGI	↓ liking scores (for higher substitution levels)	(Sparvoli et al., 2016)
Alfa alfa seed Rice flour	Data not reported	↑ protein, ↑ total dietary fibre, ↑ PUFA, ↑ antioxidant capacity, ↑ total phenolic content, hardness,↓ starch hydrolysis index (compared to control with only rice)	↓ sensory scores	(Giuberti et al., 2018)
Hemp maize	↓ WHC (for higher level of hemp flour)	↑ lightness (at increasing % of maize flour)	Biscuits made with 100% hemp flour resulted to be unacceptable. 80:20 (hemp:maize) was the best mixture	(Lukin & Bitiutskikh, 2017)
Chenopodium album (raw and germinated)	↑ WAI, ↑ WSI, ↑ OAC, ↓ viscosity, ↓ pasting temperature (germinated flour compared to raw)	↑ spread ratio (raw flour) ↓ spread ratio (germinated flour compared to raw *C.album* and wheat biscuits), ↑ total dietary fibre content for germinated flour biscuits. ↑ radical scavenging activity ↑ softness (raw flour biscuits), = softness (germinated and wheat flour)	↑ flavour score for germinated flour compared to raw and wheat flour	(Jan et al., 2016)
Rice flour Maize starch **Pea protein**	Protein addition: ↑ WBC, WHC, SV ↑ consistent dough = OAC. Starch addition: ↓ WBC, ↓WHC, ↓ SV	↓ thickness, ↓ width, ↓ hardness (at increasing % of proteins), ↑ thickness, ↑ width (at increasing % of starch)	Best score for texture and odor (rice + protein). Worst score for texture and appearance (rice + starch). Best overall acceptability for the sample with proteins but no significant differences with the control cookie	(Mancebo et al., 2016)
Lupin flour	↑ WHC	↑ spread factor, ↓ lightness	↓ lower sensory quality. Best formulation maize:lupin (50:50), lupin:maize:rice:maize starch (20:30:20:30)	(Maghaydah et al., 2013)

WBC: water binding capacity, OAC: oil absorbing capacity, SV: swelling value, WHC: water holding capacity, WAI: water absorbing index, WSI: water solubility index, EA: emulsion activity, FS: foam stability, LGC: least gelation concentration, pGI: predicted glycemic index.

3.1. Gluten free cereals in GF biscuits production

3.1.1. Rice

Rice (*Oriza sativa*) flour is already largely used in the production of GF biscuits. Rice by-products may also be used in order to enhance nutritional properties of GF products. Tavares et al. (2016) formulated GF biscuits with the incorporation of co-products generated during agro-industrial processing. They produced biscuits with the addition of toasted rice bran, broken rice flour and soybean okara. Biscuits were lighter in color, with lower water activity, and a smaller specific volume and internal and external diameters compared to the commercially available samples. Experimental biscuits had the same stability during time compared to commercial samples. Schober et al. (2003) developed a GF flour mix based on brown rice flour (70 parts), soya flour (10 parts), maize (10 parts) and potato starch (10 parts) that resulted in a good quality dough and acceptable biscuits that were comparable to wheat biscuits. Less positive results were obtained for mixtures made from brown rice flour (50 parts), potato starch (30 parts), buckwheat flour (10 parts), millet flakes (10 parts) and with brown rice flour (25 parts), maize starch (25 parts), potato starch (25 parts), soya flour (25 parts), millet flakes (25 parts).

3.1.2. Millets

Millets include cereals characterized by small kernels. They do not belong to a single species; they are grouped together on a small size basis and are categorized under coarse cereals. The most important species are pearl millet (*Pennisetum glaucum* L.), foxtail millet (*Setaria italic* L.), proso millet (*Panicum milaceum* L.), finger millet (*Eleucine coracana* L.), teff (*Eragostis tef* Trotter) and fonio (black fonio *Digitaria iburua* Stapf, white fonio *Digitaria exilis* Stapf) (Taylor & Kruger, 2016). The macro and micronutrient composition does not differ vastly between millets species but some differences have been reported (Taylor, 2017). Lipids are the only major component that differs considerably between millet species. Pearl millet and foxtail millet have higher lipid content than the other major millets. It seems that there are big differences between dietary fibre content of millets, but data are not clear since they depend on the kind of grain (de-hulled or not de-hulled) the analysis was performed on. Moreover, the home scale preprocessing (i.e. soaking, germination, pearling, fermentation, hydrothermal treatments and cooking treatments) often carried on millets can alter the nutrients composition and reduce the anti-nutrients content. With regard to micronutrients, foxtail millet has the higher calcium content (343 mg/100 g) among cereals (Taylor & Kruger, 2016). Millets are safe for celiacs since they do not contain gluten. Millet flours, mixed with other ingredients, can be useful to produce GF bakery products.

Adebiyi, Obadina, Adebo, and Kayitesi (2017) prepared 100% millet flour based biscuit through the employment of native, fermented, and malted pearl millet flour. The absence of gluten in the pearl millet flour did not adversely affect the acceptance of the biscuits. Biscuits prepared with malted and fermented millet flour had a major consumer acceptance compared to native flour. Biscuits based on malted millet flour had the best aroma, taste and overall likeness thanks to their sweeter taste and better flavour; whereas fermented millet biscuits and native millet biscuits had an unpleasant aroma and a relatively bitter taste. Fermentation and malting enhanced nutritional characteristics of biscuits; they favor in improved amino acid profile, mineral bioavailability and raised phenolic compounds in the treated samples. Adebiyi, Obadina, Mulaba-Bafubiandi, Adebo, and Kayitesi (2016) also stated that fermentation and malting of millet improves physico-chemical properties of the flour and resultant biscuit. Sharma, Saxena, and Riar (2016) used flour obtained from germinated millet seeds (foxtail, barnyard and kodo millet) in order to improve sensory appeal of GF biscuits. Germinated flour blends contained higher protein and total phenolic content and antioxidant activity than raw flour blend. Germination had a negative effect on pasting characteristics whereas functional properties were significantly improved and biscuits resulted to be sensory appealing. The use of malted, fermented and germinated millets enhances the nutritional quality of flour and baked GF products.

Teff is a typical Ethiopian cereal, used to produce the traditional pancake called injera. Among millets, teff is richer in dietary fibre and iron and contains a better protein quality and calcium compared to other cereals (Taylor & Kruger, 2016). Kenney et al. (2011) examined the effect of 25 and 50% replacement with teff flour biscuits were more brittle and less tough compared to control biscuits. No significant difference in flavor, taste, and appearance between the control and the teff flour biscuits was found. Panelists preferred the control and biscuits containing 25% of teff flour. Also Coleman, Abaye, Barbeau, and Thomason (2013)studied the suitability of teff flour to produce biscuits. Elevate proportions of teff flour in lieu of wheat flour lead to least acceptability of biscuits as determined sensorially against control group of samples. Teff flour does not have a good capacity for absorbing water since biscuit spread increased; this is in contrast with the result on biscuit spread of Kenney et al. (2011), but it is probably due to the influence of other ingredients used in combination with teff flour. The biscuits flour is generally characterized by a low protein content. Teff flour is high in protein, but it lacks of gluten protein so it does not impair biscuit quality (Coleman et al., 2013). Hence, teff flour in combination with other GF flour may be a valid ingredient for the production of GF biscuits.

3.1.3. Oats

Oats are an important source of proteins, lipids, vitamins, minerals and fibre. The consumption of oats is considered safe for most celiac people but it is still under the attention of the scientific community. Oats include many varieties with different amino acid sequences that may trigger the immune mediated response (Comino, De Lourdes Moreno, & Sousa, 2015). Furthermore, there is the possibility of cross contamination with gluten containing cereals due to post harvest management. Oat can be used as partial or total replacement for other GF flour in biscuits formulation in order to enhance the nutritional properties of gluten free biscuits. Both flour and bran may be employed. Duta and Culetu (2015) showed that different substitution levels of oat flour with oat bran increase the nutritional value and dietary fibre of the product. Higher replacement levels and total substitution affect negatively overall biscuits acceptability.

3.2. Pseudocereals in GF biscuits production

Pseudocereals flours present a better nutritional profile than the widely used GF flours (rice, maize and pure starches) in GF foods production, and their protein content is similar to wheat flour.

3.2.1. Buckwheat

One of the most studied pseudocereals for GF biscuit formulation is buckwheat (*Fagopyrum esculentum* Moench). It is characterized by a unique concentration of phytochemicals, in particular rutin. Buckwheat flour is able to maintain its antioxidant capacity after thermal treatments (Sakac, Torbica, Sedej, & Hadnadev, 2011). A replacement investigation of rice flour with buckwheat flour (10, 20 and 30% proportion) revealed high mineral availability, antioxidant potential (DPPH), phenolic level and raised rutin content when observed against control group of biscuit samples made exclusively of rice flour (Sakač et al., 2015). Also Torbica, Hadnadev, & Dapčević Hadnadev (2012) reported that mixtures of rice and buckwheat flour may be successfully incorporated into GF cereal-based products. Their biscuits had a pleasant flavour and acceptable technological quality expressed in shape, cross section structure, rupture, and appearance of top and bottom surfaces. Two other studies confirm that buckwheat based bakery product have a significant antioxidant content: Sedej et al. (2011)produced GF crackers with buckwheat flour finding a higher antioxidant content than control crackers with wheat flour and Molinari et al. (2018) found that biscuits enriched with common buckwheat flour and malted tartary buckwheat (*Fagopyrum tataricum* L. Gaertn.) have a higher phenolic content than control.

3.2.2. Quinoa

Quinoa (*Chenopodium quinoa* Wild.) is highly nutritious, has an excellent protein quality (there are all the essential amino acids) and a wide range of minerals and vitamins. The protein content of quinoa ranges between 13.81 and 21.9% depending on the variety. Although these grains are highly nutritious, very limited products are manufactured because of the absence of gluten (Thejasri et al., 2017). However, in the last few years, it is possible to find quinoa and quinoa flour in different products due to the growing interest in its healthy properties. Brito et al. (2015) developed GF quinoa-based biscuits using both quinoa flour and flakes in mixture with maize starch. Quinoa flour showed a negative effect on the specific volume whereas quinoa flour and flakes had a positive synergistic effect on the hardness of biscuits. Quinoa flour and flakes grains have a larger size than maize starch, therefore lightness of biscuits decreased at increasing percentages of quinoa flakes and flour in the mixture. Formulation with higher content of quinoa flour and flakes have a higher content of proteins, sugars and phenolic compounds. Maize starch seems to lower harness value of biscuits. Quinoa flakes and maize starch had a positive effect on the volume of the assessed biscuits. The addition of quinoa flour to wheat biscuits improved all nutritional and sensorial properties (Demir & Kilinç, 2017). The flour obtained from another plant belonging to Chenopodiaceae family, *Chenopodium album* L., has been used by Jan, Saxena, and Singh (2016) to produce GF biscuits. Researches employed raw and germinated *C. album* flour and compared the obtained biscuits with wheat flour ones. Raw *C. album* flour biscuits had the higher spread ratio, followed by wheat flour biscuits and by germinated *C. album* flour biscuits. Both raw and germinated flour decreased biscuits hardness. Biscuits made with germinated flour were softer than those containing raw flour and they presented hardness value in range with values of commercial biscuits. Structural degradation of starch and proteins induced by germination may be the main reason for decreased hardness of biscuits. The degradation of macromolecules contributed to the formation of weaker matrix in biscuit, resulting in the softer texture. Biscuits obtained with both raw and germinated *C. album* had a higher total phenolic content, DPPH radical scavenging activity and total dietary fibre content. Germination of grains imparts soothy taste to them. Thus it increases acceptability terms through high sensory score, whereas similar preparations with raw grains are on least preferences by sensory panel. However differences were not significant.

3.2.3. Amaranth

Amaranth (*Amaranthus* spp), thanks to its composition, may be useful to enhance the nutritional intake of celiacs. Its lipid content is about 6–8% and the lipid profile is similar to that of cereals and it possesses a high soluble fibre content compared to cereals. Protein content of amaranth grain is between 13 and 18% and its amino acid composition is close to the optimum for human consumption. Mineral and vitamin contents of amaranth are also considerable. Calcium, phosphorus, and iron contents are high and amaranth is also rich in antioxidant compounds, such as tocotrienols, tocopherols, flavonoids, and other phenolic compounds. Chauhan, Saxena, and Singh (2015) prepared GF biscuits from raw and germinated amaranth flour. Results showed that the use of germinated flour could lead to the production of acceptable biscuits with a good nutritional quality. Amaranth biscuits had a higher spread ratio than control wheat biscuits; high spread ratio is a desirable characteristic in biscuits. Also Inglett, Chen, Liu, and Lee (2014) found that amaranth biscuits had a higher spread ratio than wheat control, but differences were not significant compared with the control. The authors produced amaranth-oat biscuits in a 3:1 ratio, with different type of oat. Whole oat flour, oat bran concentrate and steam cooked oat bran concentrate were used. Biscuits made from amaranth and whole oat flour resulted to be more similar to the control than other combinations. Amaranth and oat composite may be useful ingredients to enhance nutritional quality of GF biscuits in terms of antioxidant compounds and minerals.

3.2.4. Legumes flour

Legume flours may be a valid ingredient to increase the nutritional quality of GF products. All species of legumes are an important source of nutrients. They are rich in proteins, complex carbohydrates, fibres, micronutrients and antioxidant compounds (Melini, Melini, Luziatelli, & Ruzzi, 2017). Nowadays, as reported in paragraph 4, legumes flours are already employed in the production of GF biscuits.

Sparvoli et al. (2016) used a cultivar of common beans with low anti nutrient content to make nutritionally enhanced biscuits. GF biscuits made from maize and bean flours were also produced. Results showed that higher percentages of bean flours reduce the sensory scores of the final product. Maize and bean flour biscuits resulted to have a lower predicted GI due to the presence of α-amylase inhibitors. Giuberti et al. (2018) tried to increase the nutritional value of GF rice based biscuits by adding alfalfa (*Medicago sativa* L.) seed flour. An overall improvement of nutritional quality was recorded. In terms of sensory properties biscuits resulted to be acceptable, but all rice biscuits resulted to have better sensory scores. Hence, it seems always necessary to use legume flour in combination with other flours. The formulation of biscuits made only with legume flours leads to unacceptable products. Also the study by Maghaydah, Abdul-hussain, Ajo, Tawalbeh, and Elsahoryi (2013) confirmed that it is not possible to produce GF biscuits exclusively with legume flours. They evaluated the possibility to use lupine flour as main GF flour in biscuits. The results showed that it is not possible to produce good biscuits with 100% lupine flour whereas acceptable biscuits were obtained using lupine flour in combination with maize flour, or maize starch, rice flour and maize flour with the addition of xanthan gum and carrageenan.

Instead of adding legume flours to the formulation, a solution to improve the quality of GF biscuits may be the addition of legume proteins, as already seen in some Italian biscuits (Table 3). Mancebo, Rodriguez, and Gómez (2016) substituted a part of rice flour in biscuits with pea protein. The addition of proteins did not have a negative impact on sensory properties and it increased dough consistency.

3.3. Fruit and vegetable seed powder

3.3.1. Hemp

Recently, a rediscovery of hemp has been seen. Seeds and leaves are used to obtain oil, flour or herb tea. Hemp seeds are rich in proteins, minerals and unsaturated fatty acids. Hemp flour may be added in biscuits formulation to improve their nutritional quality. Lukin and Bitiutskikh (2017) studied a recipe of biscuits made with hemp flour and maize flour. The best formulation resulted to be the one with a ratio of hemp:maize 80:20. Replacing 100% of the wheat flour with hemp flour leads to a significant lowering of the liking scores of the ready products. This suggests that it is not possible to produce biscuits exclusively with hemp flour but it may be used in combination with other ingredients. Hemp seed oil press cake was used in the formulation of gluten free crackers. All samples with added hemp flour had much better nutritional qualities than the brown rice flour crackers in terms of higher protein, crude fibres, minerals, and essential fatty acids content (Radočaj, Dimić, & Tsao, 2014).

3.4. Ingredients

3.4.1. Hydrocolloids

Gums and hydrocolloids are among the most important ingredients in GF formulation used to improve texture and appearance of products (Mariotti, Lucisano, Pagani, & Ng, 2009). Hydrocolloids or food gums are mostly polysaccharides. They have certain properties, such as network and film formation, thickening and water holding capacity, which

Table 3
Frequency of ingredients in GF biscuits (n. 282) available on Italian market.

Starches	%	**Fats**	%
Maize starch	80.49	Sunflower oil	40.07
Potato starch	38.65	Butter	29.08
Rice starch	21.63	Margarine	20.21
Tapioca starch	9.62	Palm oil	8.16
GF wheat starch	4.96	Olive oil	4.26
Flours	%	Coconut oil	2.48
Rice flour	78.01	Extra virgin olive oil	1.42
Maize flour	45.39	Rapeseed oil	1.06
Buckwheat flour	4.96	Canola oil	0.35
Soy flour	3.66	Maize oil	0.35
Whole oat flour	3.19	**Proteins**	%
Millet flour	2.48	Lupin proteins	3.19
Pea flour	2.48	Milk proteins	1.77
Lupin flour	1.77	soy proteins	1.06
Flaxseed flour	1.77	**Other ingredients**	%
Teff flour	1.42	Eggs	72.34
Whole teff flour	1.42	Cocoa	24.82
Oat flour	1.06	Chocolate (dark and milk chips)	16.31
Whole buckwheat flour	0.71	Albumen	4.26
Amaranth flour	0.71	Yolk	2.84
Whole millet flour	0.35		
Sorghum flour	0.71		
Thickenings and emulsifiers	%		
Guar gum	40.43		
Sunflower lectin	13.12		
Soy lectin	10.99		
Mono and diglycerides of FA	8.16		
Hydrossipropilmetilcellulose	5.67		
Carob flour	5.3		
Fibres	%		
Psyllium fibre	9.57		
Vegetable fibre (not specified)	2.84		
Apple fibre	2.48		
Pea fibre	1.77		
Inulin	1.77		
Citrus fibre	1.06		
Inulin from agave	1.06		
Maize fibre	0.71		
Rice fibre	0.35		

can be useful in the production of GF products. Since some GF flours are not able to form a firm structure, hydrocolloids may be used in order to obtain appealing baked goods with a good texture (BeMiller, 2008). It has been reported that using hydrocolloids it is possible to improve biscuits quality. Thejasri et al. (2017) added xanthan gum and guar gum to foxtail millet biscuits and gum tragacanth and xanthan gum to quinoa biscuits. In both cases authors recorded an improvement in sensory properties of biscuits as well as better nutritional properties than control wheat biscuits. Kaur, Sandhu, Arora, and Sharma (2015) and Dapčević Hadnadev et al. (2013) studied the effect of hydrocolloids on buckwheat biscuits. Kaur et al. (2015) found that the addition of gums increases water absorbing capacity, emulsion activity and oil absorbing capacity of buckwheat flour. An increase in the diameter, thickness, weight and ash content of biscuits was recorded too. Incorporation of gum increases the likeness preferences of biscuits, leading to biscuits comparable to control. Dapčević Hadnadev et al. (2013) studied the influence of buckwheat flour and CMC on the production of sheetable GF biscuit dough. The presence of buckwheat flour lowered the strength and elasticity of GF biscuit dough. Addition of CMC lead to an increase in dough firmness. The inclusion of buckwheat flour and CMC in rice dough resulted in GF dough of acceptable handling properties; the dough was soft, deformable and easy to handle in comparison to rice dough, thanks to the presence of CMC it was also strong enough to resist sheeting without sticking to rollers and maintain an acceptable shape. The absence of CMC lead to a dough insufficiently cohesive for handling and shaping. The GF dough with CMC and buckwheat flour between 20%–30% substitution level was similar to wheat biscuit dough for what concerns dough strength and resistance to deformation. These two last examples showed that minor ingredients such as hydrocolloids may be fundamental to improve GF biscuits quality. Their addition might improve the handling and the sensory acceptance of nutritionally enhanced biscuits that otherwise would present low sensory scores.

Psyllium seeds (*Plantago ovate* Forsk) contain functional hydrocolloids and are a rich source of soluble dietary fibres (de Mello Castanho Amboni et al., 2013). Psyllium fibre, obtained from psyllium husks, is already employed in some commercial GF products. Different research reported the possibility to employ psyllium fibre in GF breads (Cappa, Lucisano, & Mariotti, 2013; Mariotti et al., 2009). Raymundo, Fradinho, and Nunes (2014) studied the effect of psyllium fibre addition to wheat biscuits to enrich their fibre content. The same use could be done for GF biscuits. Nothing is reported about the use of psyllium in biscuits but psyllium is the most employed source of fibre in biscuits (Table 3). The addition of psyllium to a formulation to enrich the fibre content requires attention because of the strong water biding capacity of psyllium fibre as well as of other hydrocolloids. They could compromise biscuits characteristics.

3.4.2. Inulin

Inulin belongs to fructans, a group of non-digestible carbohydrates, it is usually employed as fat or sugar replacer in food products and it is also employed as fibre source and for its prebiotic action. Different benefits may results from inulin ingestion, including enhancement of mineral absorption (Shoaib et al., 2016).

Different percentages of oligofructose-enriched inulin were used to replace rice flour in chocolate biscuits in order to obtain a product that could promote calcium absorption in celiacs. Biscuits with 25% substitution of rice flour showed a good acceptance whereas biscuits with higher substitution had lower liking scores due to their minor grittiness and lower fracturability and intensity of aroma, flavour and textural properties (da Silva & Conti-Silva, 2018). Inulin type fructans have the potential to improve technological properties and sensory perception of baked products (Drabińska et al., 2016). Inulin can also be a useful ingredient to reduce GI of GF biscuits.

4. Ingredients of GF biscuits available on Italian market

The ingredients of 282 GF biscuits listed in the Italian National Register of GF products were collected and analysed in order to find out the most occurring ones. Ingredient lists were taken from producers' webites and they were collected in the period between December 2017 and Febrary 2018. Microsoft Word and Microsoft Excel (Microsoft Office 2013) were used to collect, adjust and analize the data. Lists of composed ingredient such as chocolate, filling creams and jams, margarine etc, were deleted from the data.

Over 400 different ingredients were present in the analysed biscuits sample.The most frequent ingredients were maize starch, rice flour, eggs, sugar, salt, maize flour, guar gum, potato starch, leavening agents, sunflower oil, aroma and butter. Some ingredients are the same reported by do Nascimento, Fiates, dos Anjos, and Teixeira (2013) in Brazilian GF foods (baked products, granola and pasta). Authors found that rice flour, eggs, cassava fecula, natural maize, soy flour, rice and vanilla are the most frequent ingredients. Table 3 reports the frequency with which flours, starches, thickenings, emulsifiers and fibres appears on the label of GF biscuits. Maize starch and rice flours are in 80.5% and 78.0% of biscuits whereas more nutritious flours like buckwheat flour, teff flour and millet flours are present in percentages smaller than 5%. Even if they are not widely used, these data demonstrate the intention of producers to place on the market a varied and better choice of GF biscuits and their attention to consumers needs. Rice and maize flours and starches have a blend flavour, are less expensive than other flours. Usually GF biscuits lack in fibres but sometimets they are added to biscuits. Legume flours are also added with the purpose of increasing protein content of final product. Moreover, if proteins and fibre content is increased, there is a beneficial effect on GI and GL of the biscuits. Often chocolate chips, dark chocolate and cocoa are included in the recipe, and there is also a quite wide choice of filled GF biscuits. Fillings are mostely represented by chocolate creams and jams.

5. Conclusion and future trends

The use of unconventional GF flours, that are not represented by starches, maize and rice flour, can significantly improve the nutritional and functional quality of GF biscuits, with an increase of fibre content, protein content, vitamin, mineral and antioxidant compounds and a reduction of starch content. Malting, fermentation and germination may improve the overall quality of biscuits by minimizing all of the antinutrients and by enhancing bioavailability of nutrients. Their employment in GF products should be considered. Mixtures of ingredients are useful to obtain an appealing biscuit since each ingredient can provide a specific effect on dough and final product. In view of environmental sustainability and fight again food waste, a trend that may be followed is the use of agroindustrial by-products in the formulation of GF biscuits. In example, Matejová, Fikselová, Curlej, and Czako (2016) added grape pomace in the recipe of GF biscuits. Singh and Kumar (2018) used copra meal flour, a by product of coconut processing, in order to reduce fat and sugar content of GF biscuits. Pomace and other byproducts from agro industrial processes may be employed so as to improve nutritional quality of biscuits representing a good source of fibres, antioxidants and different micronutrients.

The analysis of the label of 282 GF biscuits available on Italian market highlighted the need to improve the composition of biscuits. Some breakthroughts have been made in the last years, but more nutritious ingredients appear only in a very small part of GF biscuits. Researchers and producers shoud continue to focus on the improvement of nutritional quality of GF biscuits and foods in general without forgetting the importance of sensory quality. Moreover, an effort should also be made to reduce the glycemic index of GF biscuits through the use of selected raw materials.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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