Biological Forum – An International Journal **15(5): 1018-1023(2023)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Applications of Gluten-free Flours in Bakery Products Formulations: A Review

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(Received: 19 March 2023; Revised: 15 April 2023; Accepted: 28 April 2023; Published: 20 May 2023)
(Published by Research Trend)

ABSTRACT: Rising incidence related to gluten illness, have gained significant attention and more demand for gluten free diet. Generally, it is more difficult to make bakery and food products without gluten protein in wheat, barley and rye. It is necessary to find gluten-free substitute for baking ingredients as well as innovative ways to prepare existing ones. It is not limited with population with gluten-related problems, but also those who prioritize maintaining a healthy lifestyle and following a gluten-free diet, can be traced for the increase in demand for gluten-free goods. This review highlights potential of gluten free flour to as substitute to conventional wheat flour. The quality of gluten-free goods is among the most challenging things to develop. To produce gluten-free products, it is usual to fall back on the use of gluten-free flour either from cereal or from other grains, such as legumes or pseudo cereals. During products preparation, factors need to consider that affect the functionality of gluten-free flours. The main objective of this review is to provide an overview on the use of gluten-free flours in basic bakery products such bread, cakes, and cookies. This article also summaries various nutritional, functional, and physiochemical properties of different gluten-free flours and the applications of novel technological approaches. Various strategies used to enhance bakery goods free of gluten will produce a range of excellent results.

Keywords: Gluten free flour, amaranth flour, buckwheat flour, bakery products.

INTRODUCTION

Gluten is a functional ingredient, and it is very well-known for its viscoelasticity characteristic in various food products (Brockow *et al.,* 2015). Gluten is a protein found in certain grains, including wheat, barley, and rye. The two main proteins in gluten are gliadin and glutenin. When flour is mixed with water, these proteins form a sticky, elastic network that gives dough its texture and helps it rise during baking. Besides, gluten proteins are characterized by high proline and glutamine content which can cross the epithelial barrier and stimulate the immune system subsequently trigger an allergic reaction or autoimmune response such as celiac disease (Ortiz *et al.,* 2017). The immune system recognizes gliadin as a foreign invader and attacks the lining of the small intestine, causing damage and inflammation.

According to Codex Alimentarius International Food Standards, Gluten-free foods can be produced from natural gluten-free ingredients or from components comprising wheat, barley, rye, or crossbred variants of these grains that undergoes processing to eliminate gluten, if the amount of gluten per kilogramme does not exceed twenty milligrams. Gluten-free goods are intended to be an excellent option for individuals with gluten-related diseases. The three most common gluten-related disorders are celiac disease, non-celiac gluten sensitivity, and wheat allergy (Roszkowska *et al.,* 2019). Celiac disease is an autoimmune disorder in which the immune system reacts to gluten and damages the lining of the small intestine. This damage can lead to malnutrition, digestive problems, and other health issues. Non-celiac gluten sensitivity is a condition in which people experience symptoms like those of celiac disease when consuming gluten, but do not have the same immune reaction or intestinal damage. Symptoms can include digestive issues, headaches, fatigue, and joint pain. Wheat allergy is an allergic reaction to proteins found in wheat, which can cause symptoms such as hives, difficulty breathing, and anaphylaxis in severe cases. In fact, the only effective treatment to avoid triggering the effect of gluten-related disorders is by eliminating any gluten food sources completely out of their diet (Benjamin and Brooks 2018).

Gluten-free flour is made from grains and starches that are naturally gluten-free, such as rice, corn, potato, chickpea, almond, and coconut. It can also be made from blends of these ingredients. It is commonly used in making gluten-free bread, cakes, cookies, and other baked goods. It is also used in savoury dishes like sauces, soups, and batters for frying. Gluten-free bakery products that are prepared with gluten-free flours often tend to have reduced quantities of fiber, proteins, iron, and B vitamins compared with wheat products (Matos and Rosell 2011). Produce goods with a nutritional composition that is equivalent to that of their gluten-containing equivalents, the design of gluten-free bakery items must be modified. The function of a few alternative ingredients that can enhance GF bakery products, such as alternative starches and flours,

hydrocolloids, proteins, enzymes, and lipids, has been discussed in scientific literature (Naqash *et al.,* 2017). The dough made of gluten free products is difficult to shape, which is the main technological problem in the production of confectionary products (Gambus *et al.,* 2001). The preparation of gluten-free bakery products requires application of different flours in exchange for wheat flour, so the resulting taste very often does not resemble that of classical, gluten products. The role of food technologists is to design such as for gluten-free products, which would improve their expansion, structure, and taste (Gambus *et al.,* 2001).

SCOPE OF STUDY

The importance of gluten free flours in food industry have significantly increased in recent decade due to their potentials as substitute for wheat, barley and rye flour. Gluten free flours are essential to individual with gluten related disorders, gluten sensitivity and wheat allergies. This study focused on potentials of different gluten free flour for food applications due to their versatility and functionality. This increased demand for gluten free flours suggests better option for food industry to cater need of consumers. The food industry can adapt to changes in the market while responding to client needs and preferences as well as those of a diverse consumer group, by recognizing the importance of Gluten Free flours.

Gluten and Health Benefit. There are many scientists and researchers who study gluten-free diets and their impact on health. These include nutritionists, gastroenterologists, immunologists, and other specialists. One well-known scientist who has researched the effects of gluten-free diets is Alessio Fasano, the director of the Centre for Celiac Research and Treatment at Massachusetts General Hospital. Fasano (2015) has conducted extensive research on celiac disease and gluten sensitivity, including studies on the prevalence of celiac disease and the potential benefits of a gluten-free diet for people with non-celiac gluten sensitivity.

For people with dyslipidemia who do not suffer from celiac disease or gluten sensitivity, gluten itself might be beneficial for their diets. Increased intake of wheat gluten for two weeks while on a weight-maintenance diet decreased blood triglycerides by 13% in persons with hyperlipidemia. Additionally, gluten may strengthen a person's immune system. The extremely high glutamine content of gluten may be a contributing factor in this. Gluten may aid in the regulation of blood pressure in addition to its potential advantages for lowering blood lipid levels (Jenkins, *et al,* 2001). Wheat and other gluten-rich grains, particularly, may provide health advantages due to both naturally existing fructan-type resistant starches and gluten itself. Whole-grain wheat products can protect the gut from various malignancies, inflammatory diseases, and cardiovascular disease by fostering a balanced composition of colon bacteria.

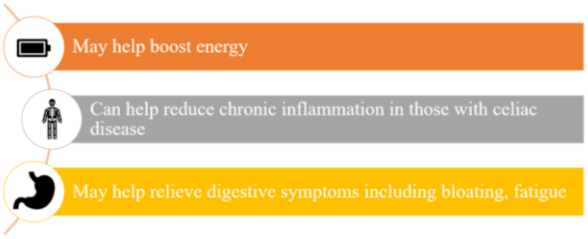

Fig. 1. Benefits of Gluten-free diet.

Gluten-free flours. Based on product type, gluten free flour market is segmented into amaranth flour, almond flour, oat flour, corn flour, bean flour, maize flour, coconut flour, and others.

Almond flour. Sometimes called almond meal, it is made from finely ground almonds with or without their skins. Flour made with skin-on almonds will have a darker color and is suitable for rustic breads or baked goods that also have a dark color, such as chocolate desserts or gingerbread. Almond flour without the skin is made from blanched almonds and has a light ivory color. It can be used in light-colored cakes and muffins. It has fewer carbs, more nutrients, and a little sweeter taste. In comparison to wheat flour, almond flour has additional health benefits, such as lowering “bad” LDL cholesterol and insulin resistance. The nutritional value of food is increased by adding AF in proportions of 20%, 40%, and 60% (Daniela Stoin *et al.,* 2018).

Amaranth flour. Amaranth is a nutritious, gluten-free grain derived from the amaranth that provides plenty of fiber, protein, and micronutrients. It is high in protein, with a nutty flavor, it is used in baked goods and pasta. Amaranth affected the factors that determine dough texture, reducing dough elasticity and increasing softness. The amaranth substitution improved the quality of the GF flatbreads by increasing all the polyphenol fractions, particularly the bio accessible fraction, in addition to the protein and ash content. It has phytochemicals that are great for acting as antioxidants. It is a superfood and a major source of calcium, manganese, potassium, vitamin C, iron, and B vitamins. Although it should be blended with other flours when baking, it can replace 25% of the wheat flour (Cotovanu *et al.,* 2021).

Buckwheat flour. Despite its name, buckwheat is not wheat and contains no gluten. It has a distinctive earthy flavor. The small seeds of the plant are ground to make flour and it has a rich, earthy flavor that works well in quick breads and yeast bread. Buckwheat-based crackers have a greater total phenolic content than wheat-based crackers. In compared to wheat crackers, they have a tocopherol level that was higher (Ivana Sedej *et al.,* 2011). A reliable source of balanced protein and eight essential amino acids, this flour also contains B vitamins, manganese, fiber, copper, magnesium, and other minerals. It is available in light, medium and dark varieties.

Coconut flour. Coconut flour is gluten-free flour made from the fruit of the palm tree *Cocos nucifera*. It can be used to replace some of the wheat flour in a recipe, or it can be combined with other gluten-free flours to make a gluten-free flour blend. This flour has a delicate

coconut flavor, pale ivory color, and is high in fiber. It improves heart health, healthy digestion, and stable blood sugar levels. Coconut flour's water-binding properties led to a reduction in the amount of flour needed to create the desired product (Hopkin *et al.,* 2022)

Corn flour. Corn Flour is gluten-free in its natural form. It is also known as maize flour, is a type of flour that is made by grinding whole corn kernels into a fine powder. It is commonly used in Latin American and Caribbean cuisines, where it is used to make dishes such as tortillas, tamales, and arepas. Technology allows to produce consumer-acceptable bread with 20% corn flour instead of wheat flour (Grassi *et al.*, 2020). It is a useful source of fiber, vitamins, and minerals such as iron and potassium. However, it is lower in protein compared to wheat flour. It has a light, finer texture when used in baked goods. Cornmeal is used to make cornbread, muffins, hushpuppies, fritters, and polenta.

Sorghum flour. Also called milo or jowar flour, it is made from grinding whole grain kernels of the sorghum plant. Available in red and white varieties, it has a slightly sweet taste. Sorghum based gluten-free cakes offer better nutritional value (Cátia *et al.*, 2021). The textural features of gluten-free cakes were improved by phosphorylation of sorghum flours. It is high in antioxidants. It is high in protein, dietary fiber, iron, phosphorous, potassium, B vitamins and minerals, which help maintain blood sugar stability and may also help with digestion. It is also an excellent choice for pancakes, breads, muffins, and cookies.

Brown Rice flour. As the name suggests, this flour is made from ground rice flour or white rice flour. This is a whole-grain flour as it contains the bran, the germ, and the endosperm. This type of flour is a rich source of essential amino acids, dietary fiber, protein, and a variety of other vitamins and minerals. Brown rice flour can be substituted for wheat flour on 1:1 ratio when used as a thickening agent in soups, sauces, or gravies. It does have a slight nutty taste and is used to make noodles, breads, cakes, and cookies. Moderate milled BRF improved the characteristics of dough and gluten-free bread (Jiangping *et al*., 2021).

Oat flour. Oat flour is a type of flour made from whole oats that have been ground into a fine powder. It is a popular gluten-free alternative to wheat flour, as it is high in fiber, protein, and other nutrients, such as manganese, phosphorus, and vitamin B1. Oat flour has a mild, slightly sweet flavor that works well in a variety of recipes, including bread, pancakes, muffins, and other baked goods. Oat flour has a high biological value and is a strong source of proteins. The flour is an intriguing additive for the creation of white bread, both wheat and wheat-rye, and might be employed in the amounts up to 20% of wheat flour mass due to its beneficial amino acid composition and high concentrations of nutritional fibre and fat (Halina Gambuś *et al.,* 2011).

Quinoa flour. Quinoa flour is a type of flour made from ground quinoa seeds. Quinoa is a nutrient-dense grain that is high in protein, fiber, and various vitamins and minerals, including iron, magnesium, and potassium. With its mild nutty flavor and pale color, quinoa flour can be used for both savory and sweet recipes. It is excellent in cake and cookie recipes as well as breads and muffins. The product thickness values of the cookie samples slightly increased because of the usage of Quinoa flour. Additionally, diameter values fell as Quinoa flour levels in cookie formulation increased, however a substantial decrease was not noticed with the addition of 10% Quinoa flour (Demir and Kılınç 2017).

Chickpea flour. Chickpea flour, also known as gram flour or besan, is a type of flour made from ground chickpeas (also called garbanzo beans). It is commonly used in Indian, Middle Eastern, and Mediterranean cuisines, where it is used to make dishes such as pakoras, falafel, and socca. Chickpea flour is gluten-free and high in protein, fiber, and other nutrients, such as iron, magnesium, and potassium. The protein, fiber, and mineral content of the bread enhanced with the addition of chickpea flour to wheat flour. Sensorial analysis was used to determine whether the Chickpea flour enriched breads were acceptable and found that samples containing up to 10% Chickpea flour had satisfactory organoleptic qualities (Simona *et al.*, 2015).

Social demand for Gluten-free food. The demand for gluten-free products has been steadily increasing in recent years. Not only the population with gluten-related problems, but also those who prioritize maintaining a healthy lifestyle and following a gluten-free diet, can be traced for the increase in demand for gluten-free goods. As a result of this increased demand, there has been a proliferation of gluten-free products on the market, including specialty stores and restaurants that cater to gluten-free diets.

Gluten Free Flour Market size was estimated at $5.6 billion in 2020, projected to increase at a CAGR of 8.1% during the forecast period 2021-2026. In recent years, there has been a dramatic increase in the elimination and restriction of gluten from diets (Gujral *et al*., 2012). According to Croall *et al.* (2019), not only the population with gluten-related problems, but also those who prioritize maintaining a healthy lifestyle and following a gluten-free diet, can be traced for the increase in demand for gluten-free goods. The consumption of GF products will keep an increase in the future.

To address the rising demand for gluten-free bread, packaged bread companies are creating free-from sub-brands under their main brands, which are gaining popularity among customers from all socioeconomic levels. Furthermore, a number of brand-new bakeries are now offering gluten-free bread that not only complies with all health requirements but also with raw, organic, vegan, and paleo diets. Some of these start-ups are concentrating on exploiting neglected crops like coconut, which need less water to grow and are packed with important amino acids. Some of them also offer plant-based Gourmet Bars, which are protein bars without gluten. These bars are lactose-free, casein-free, and gluten-free and include whey protein in addition to organic raw almonds. These foods have gained

enormous traction during last few years because of surge in celiac disease cases.

Gluten- free bakery products. Gluten free bakery products can be prepared using different ingredients as a substitute to wheat flour. Studies carried out to prepare gluten free bakery products are summarized in following Table 2.

Table 1: Comparison of Nutrient Composition of different Gluten-free Flours.

Flour name	Nutritional value per 100g				
	Calorie (Kcal)	Protein (g)	Fat (g)	Carbohydrates (g)	Sodium (mg)
Almond flour	610	21	54	12	6
Amaranth flour	374	14	7	65	4
Buckwheat flour	343	74	13	3	1
Coconut flour	400	19	8	58	35
Corn flour	361	76.8	7.1	1.2	7
Sorghum flour	339	72.8	10.6	3.3	6
Brown rice flour	366	7.5	76.2	2.8	8
Oat flour	389	66.3	13.1	6.9	2
Quinoa flour	375	64	14	6	6
Chickpea flour	387	58	22	6	21

Source: United States Department of Agriculture (USDA) National Nutrient Database

Table 2: Formulation of gluten free bakery products.

Sr. No.	Product	Composition	Reference
1.	**Cake**	Soy flour of three particle sizes (<132, 132–156 and >156 μm) were used to substitute 15% and 30% of starch in layer and sponge cakes formulations.	(Nahla *et al.*, 2016)
		Using sorghum flour, gelatinized corn flour, germinated rice flour, rice flour and their blends for production of gluten-free cakes suitable for celiac patients.	Ahmed et al., 2012
2.	**Biscuits**	Corn-based flour, which was partially substituted with 5, 10, 15, or 20 % of either crushed, shell-less walnuts (WN), peanuts (PN), or their combination (1:1).	(Amin *et al*., 2023)
		Corn flour and starch were used to produce gluten free biscuits with functional properties	(Saleh *et al*., 2010)
3	**Cookies**	Formulations of gluten-free cookies based on rice flour and buckwheat malt or flour in ratios 70:30, have been produced	(Romina *et al.*, 2017)
		Nine gluten-free formulations were developed: control (C1-100% rice flour and C2-100% quinoa flour) and samples with quinoa flour (87%) and with the addition of pea protein powder, pumpkin seed protein powder, coconut flour, aronia powder, carrot powder, tomatoes powder and ginger powder with a concentration of 13%.	(Iulia, 2021)
4.	**Muffins**	Substitution of rice flour (control) with teff flour at 25%, 50%, 75% and 100% on the physical, textural, and sensory characteristics	(Valcarcel *et al*., 2012)
		Development of a gluten-free muffin based on green banana flour and evaluated their physical–chemical and sensorial aspects.	(Radünz *et al.*, 2022)

Technological advances in processing of gluten free Bakery products. The food technologists encounter difficulties related to pasta, bread, and bakery goods. Due to the absence of gluten, it is hard to preserve the texture, volume, shelf life, and sensory quality of the respective products. Gluten- free breads hardens more quickly and crumbles easily. Majority of cereal grain proteins are composed of water-insoluble prolamins and glutelin, also known as gluten. These cereal proteins are crucial in terms of technology. Gluten has a distinctive structure and viscoelastic gel, which provides wheat dough and other baked goods their distinct qualities. A three- dimensional viscoelastic system of gluten is sufficient and flexible to support a required volume of gas, assuring the necessary volume, form, and texture of the products. The volume and cohesion of the dough must be preserved while preparing bread and baked goods using gluten- free raw materials. The rapid deterioration of these products is a critical concern. Different processes can be used to modify the functional properties of gluten free raw materials to improve the quality of final goods.

High- pressure processing (HPP). Several technological techniques have been employed to imitate the functionality of gluten and thereby enhance the sensory and quality properties of gluten free products. Physical modification of the raw material such as flours and starches are safe and efficient as they are not considered food additives, resulting in clean labels. Especially, the High- pressure processing (HPP) has been an interesting topic of discussion among the researchers because it alters the basic capabilities of the food components for instance; protein denaturation, starch gelatinization or increase in triglycerides fusion point while preserving the taste, color, flavour, freshness and nutrient content of the final product (Gutiérrez *et al.*, 2022). It is a non- thermal process that has gained popularity in recent years. In gluten- free products, HPP has been used as a method of ensuring product safety and quality while maintaining texture and flavour. This method is considered as an alternative

to other basic heat treatment methods. It can enhance the bread crumb value and delaying the staling. Overall, the use of HPP in gluten- free products shows promise as a means of improving product safety and quality. However, further research is needed to fully understand the effects of HPP on gluten- free products and to optimize the technology for specific products and applications (Kieffer *et al.,* 2007).

Sour-dough fermentation. Commercialized gluten-free products (GFP) typically have technological issues with the dough's elasticity and cohesion as these two qualities are supplied by the gluten protein. GFP are considered inferior to gluten containing products in context of sensory attributes. Sourdough contains flour and water, and sourdough fermentation is a method of bread making that involves the use of naturally occurring lactic acid bacteria (LAB) and yeast. Sourdough fermentation has been shown to improve the texture of gluten-free products by increasing the viscosity of the dough and promoting the formation of a more elastic crumb. This happens due to the acidification of the dough by lactic acid bacteria, which creates a more stable protein network while the primary function of yeast is CO_2 production. The fermentation process breaks down complex carbohydrates, making them more digestible and increasing the bioavailability of nutrients. Additionally, sourdough fermentation can reduce the glycemic index of bread, making it a better option for individuals with diabetes. However, there are some limitations to using sourdough fermentation in gluten- free products. One challenge is finding the appropriate starter culture, as different strains of bacteria and yeast can have varying effects on the final product. Also, the fermentation process can be more variable and difficult to control in gluten-free baking, which can lead to inconsistent results.

Extrusion processing. Another technique that can help to improve the quality of gluten free products is extrusion treatment. Extrusion involves the use of heat, pressure, and mechanical shearing to transform a dough-like mixture into a continuous, uniform product. In the case of gluten-free products, extrusion can help to improve the texture and appearance of the final product. It can also be used to create different shapes and sizes of products, such as pasta, bread, and snacks. Also, numerous studies have demonstrated how using extruded quinoa, rice-corn, and buckwheat flour in the production of gluten free (GF) bread results in an increase in a particular volume and a decrease in bread firmness. During extrusion, the dough is typically made from a combination of gluten-free flours, starches, and other ingredients that are blended to create a cohesive mixture. Moreover, extrusion treatment has been claimed to improve cookie quality and aid in stabilizing dough foam in biscuits (Lisovska *et al.,* 2020). Extrusion can also help to reduce the levels of anti-nutrients in gluten-free flours, which can make them more digestible and nutritious. However, it is important to note that extrusion may also cause some nutrient loss, particularly with respect to heat-sensitive vitamins and minerals. Overall, extrusion can be a useful tool in the production of gluten-free products, but it should be used judiciously and in conjunction with other processing methods to ensure the final product is of high quality and meets the nutritional needs of consumers.

FUTURE SCOPE

The demand for gluten free flours and their products offers potential application in food industry due to increasing awareness of gluten sensitivity among population. Many people prefer to follow gluten free diet for different reasons which suggests better opportunity to explore gluten free flours. Consistent innovation related to product formulation from gluten free flours is needed to meet consumers expectations. Novel processing technologies may be utilized to improve functional and textural quality of food products. The major challenge associated with gluten free flour is to achieve desired taste and texture of product. Future efforts to put in research and development will focus to improve sensory properties of gluten free flour and their products. Applications of gluten free flours should not be limited to bakery goods, as versatility of gluten free flours suggests diverse use in extruded foods, snacks and other foods.

CONCLUSIONS

The demand for Gluten free food is projected to continue increasing in the future. Gluten free food development is still technically difficult, although research continues to find innovative techniques and methods that could offer a more effective solution for gluten free product development. It could be possible to prepare non-gluten bakery products like bread, cakes, and biscuits using single or combination of flours consisting cereals, pseudocereals, and legumes. In addition to ingredients, the use of innovative technologies yields additional solutions for the manufacture of high-quality gluten free products. Extrusion technology has the potential to improve starch gelatinization, which results in better functional properties and structural attributes. High-pressure treatment has the potential to form protein networks and starch gelatinization. Overall, efforts in the future should be concentrated more on advanced technological strategies, particularly those involving the high-pressure process and extrusion technology, both of which are promising in terms of product quality and time efficiency. However, there are still very few findings, especially in gluten-free bakery goods other than bread.

Acknowledgment. We thank to Dr. Manmath Sontakke for assistance and encouraging us to write this need-based topic. Also thankful to Department of Food Technology and Nutrition, Lovely Professional University, Phagwara, Punjab for utilizing resources and facilities.

Conflict of Interest. None.

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How to cite this article: Akriti Thakur, Jaismeen and Manmath Sontakke (2023). Applications of Gluten-free Flours in Bakery Products Formulations: A Review. *Biological Forum – An International Journal, 15*(5): 1018-1023.