

Review Article

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## Recent Advances in Development of Multi Grain Bakery Products: A Review

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### ABSTRACT

In the past few years, the food sectors have shown more attention towards the functional food development. The erudition of the effects of processing as well ingredient composition is essential in order to optimize the conditions and to obtain functional foods affluent in bioactive compounds. Particularly natural antioxidants present in food have received significant interest because of their safety and potential alimental and therapeutic effects. Since way back, bread and bakery products play a predominant role in human nutrition. Numerous cereal related bakery and non-bakery products have been put into engenderment including bread, biscuits, snacks, cookies, noodles, tea, sprouts, and so on. However, a trend has been noticed for an increased need for tastier and nutritionally affluent bakery items prepared with various cereals and plant seeds nowadays. An incipient business has emerged through that demand for companies specialized in the manufacturing of stabilized multigrain bakery products. This review is engrossed on current advances in enriching the bakery products with natural raw materials affluent in bioactive compounds specifically cereals and seeds as well as their overall nutritive value and consumer approval. Conclusively, the long run trends in several multigrain products processing are also addressed.

#### Keywords

Functional food,  
Multi grain, Bakery  
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### Introduction

Last decades, the food sector influences the economy in several nations in relation to the significant contribution for the processing of agricultural raw materials and food supply. In recent years, consumer demands and expectancy in the field of food production have changed impressively. Today foods aren't meant to only satiate hunger and to offer necessary nutrients for humans but additionally to stop nutrition-related diseases

and improve psychological and physical well-being (Betoret *et al.*, 2011). Thus, the development of new functional foods is one of the most attractive trends in the food market. Functional foods are the ones that exert a scientifically proven specific health benefit beyond their nutritional entity even if the consumption of the specific formulation is not much necessary for human life. A number of the functional foods such as fortified beverages, juices, milk, yoghurts, margarine, cereals, etc. produced nowadays based on the consumer perspective and market demand.

These products are gaining interest for an increasingly health-concerned society and may be especially relevant for obviating or delaying a number of age-cognate diseases (Giménez-Bastida *et al.*, 2015).

Cereals are the ascendant crops in world agribusiness, and they are the first source of calories and protein to the diets of humans. Now-a-days, cereal-based confectionery products comprise a colossal group of products which differ in composition, production methods and sensory attributes. They are widely accepted and consumed by all categories of consumers, eaten afore and after repasts throughout human lives. Supplementally, they have long shelf-lives which make them convenient for use. They are considered to be a concentrated food due to high contents of carbohydrates, fats and low moisture contents. Therefore, they supply a substantial amount of energy to the diet. Enrichment of foodstuffs with functional elements like cereals and seeds has been commonly utilized so that they can improve their pro-health qualities. In this regards, bakery products are consumed in colossal quantities daily and thus, providing a convenient medium for distributing dietary fibre and other salubrious compounds to consumers. Also, in developed countries, more than 50% of the total energy intake is from cereal food products (e.g. bread, cookies etc.) emerging them the best vehicle for the functional supplements (Akhtar *et al.*, 2011). To date, the incorporation of bran from different cereals has become the most mundane practice of incrementing dietary fibre in baking, but lately, other sources such as malt and whole grain have made popularity.

Realizing the adversity of these refined products, the enhancement of the nutraceutical prospective of bakery items through fortification has appeared as an incipient trend with some effective tests. Bakery items with

raised levels of antioxidants and fibre are in popular requirement because of their positions in the protection and enhancement of health and security against many diseases (Sivam *et al.*, 2012). However, there was very less number of extensive evaluation report enlisted regarding all facets of bakery items enriched with natural resources to boost the nutritional and functional value (Dziki *et al.*, 2014). Thus, this article focused on recent findings and advances in the productions of various bakery product mixed with or without wheat by the addition of cereals and seeds highly rich in bioactive compounds.

### **Nutritional quality of cereal grains used in bakery products**

The functional and nutritional qualities are the two essential factors that depict the relevance of cereal products as individual foods (Henry *et al.*, 2016). At the same time, the grain must have the qualities required to allow efficient manufacture of a food product with the physical and organoleptic qualities appropriate or appealing to humans. This is the perspective that drives individual's demand yet cereal grains make a critical commitment to both the calories and protein parts of the human diet. Additionally, the composition of cereals also has a significant influence on the health of human being (Henry *et al.*, 2016) as well as a key aspect in imparting the quality of processed products (Qiang *et al.*, 2017). Concisely, the mixed grain (multigrain) products can address the above requirement in an efficient manner.

Most of the cases multigrain products like bakery items are prepared with or without wheat flour along with various cereal grains as well as oil seeds. Oats, corn, soy, barley, rye, rice, amaranth, triticale, and buckwheat are most regularly utilized cereals in multigrain bakery products to enhance structure, flavour, texture, nutritional variety and consumer

acceptability. These cereal grains are the vital resource of carbohydrates, protein, dietary fibre, B vitamins and minerals (Table 1). These are also characterised by their rapid glycaemic responses, and refined ingredients such as sugar and fat. In all cereals feed, the major types of energy arise from starchy part, proteins and to a smaller extent, fats. These cereals additionally incorporate a significant amount of non-digestible cell wall polymers (dietary fibre), minerals, vitamins and phytochemicals in the diet. These nutrients concentration and kinds may vary in different grains. Also, cereals are rich source of B vitamins such as thiamin, riboflavin, and niacin as well contains a significant level of vitamin E (McKevith, 2004).

Likewise, wholegrain cereals are abundant in iron, magnesium, and zinc with a minor quantity of many trace elements like selenium (McKevith, 2004). Additionally, the non-starch polysaccharides (NSP) considered as insoluble and soluble, are an affluent source in all most all the cereal grains where the insoluble NSP is similar in most cereals with differed water-soluble NSP. The most important water-soluble NSP in wheat, rye, and barley is arabinoxylans while oats are rich in  $\beta$ -glucans. Comparatively, the levels of  $\beta$ -glucans and arabinoxylans are higher in barley, oats and rye than wheat (3–11 %, 3–7 %, 1–2 % and <1 %, on dry weight respectively) (McKevith, 2004). So as to enhance the nutritional value, the consumer end products should fortify with various cereal grains as much as possible to give a finished result. Thus, the foods abundant in wholegrain and dietary fibre and with sluggish glycaemic values have health-protective effects which triggered the interest in creating a new technological innovation to boost the nutrition profiles of cereal foods, and to regulate physiological activities in consumers (Poutanen *et al.*, 2014).

### **Bakery products fortified with different**

### **cereal grains**

In the recent years, the bakery industry focused on developing innovative bakery products by utilizing the health-promoting role of various cereals and seeds. Specifically, the bioactive elements within the cereal flour demonstrated numerous positive effects on health. Therefore, the diversification of different bakery items (bread, cookies, cakes, biscuits) from raw materials with potential functional constituents along with the optimization of process parameters and formulations, and the depiction of end products with regards to sensory and physicochemical properties are obtaining a substantial curiosity. The prevention of non-communicable diseases, variety in diet and importance of functional foods become the prior focus of the food industry and researchers to continuously enhancing the variety, quality, taste and availability of food products.

### **Bread enriched with various cereal grains**

Wheat bread is a staple food in the human diet in several nations around the world. The principal constituents of wheat bread are wheat flour, yeast, sugar, and salt. Bread is of two type i.e. leavened or unleavened bread. In leavened bread, the leavening agents (baker's yeast or baking powders) in dough produce carbon dioxide resulting in bread aeration. In contrast, there is no carbon dioxide generation in unleavened bread and resulting in flat and dense bread production (Martins and Ferreira, 2017). However, the inherited factors and the sort of wheat and flour utilized for bread preparation are the key factors for the beneficial effects of bread (Adom *et al.*, 2003).

Bread prepared from regular wheat flour (*Triticum aestivum* L.) has minimal antioxidant potential compared to the bread

prepared from wholegrain wheat flour (Gunenc *et al.*, 2013). Hung *et al.*, (2009) reported that the antioxidant activity of the whole grain flour was three times higher than that of white flour. Wheat flour is often mixed with rye (*Secale cereale* L.) flour to enhance the nutritional quality of rye based bread as rye grains are rich in essential phytochemicals (Bondia-Pons *et al.*, 2009; Zielinski, *et al.*, 2008). Hauswald *et al.*, (2010) showed that rye bread mixed with whole-wheat flour exhibited high antioxidant potential, B-complex vitamins and dietary fibre with low potential harmful compounds, viz. acrylamide, hydroxymethylfurfural, and furfural.

Oat (*Avena sativa* L.), despite the fact that is consumed in substantially lower levels globally compared to wheat and rice, is a supplier of numerous compounds which demonstrate its higher antioxidant activity such as phytic acid, vitamin-E (tocopherols), phenolic compounds, and avenanthramides, flavonoids, and sterols (Peterson, 2011; Popa *et al.*, 2012). Brindzova *et al.*, (2009) revealed that wheat bread mixed with oat flour showed a higher antiradical potential.

Flander *et al.*, (2007) showed that oat based bread has nutty, gentle and relaxing flavour. McKechnie (1983) documented that oats enriched bread may be retained fresh for an extended time because of good moisture retention property of oats. It has been reported that the bread staling rate became slow down upon agglomeration of oat starch or oat lecithin with wheat bread (Zhang *et al.*, 1998). Moreover, Dziki *et al.*, (2014) described that oat is highly rich in dietary fibre,  $\beta$ -glucan which enhance the functional properties of wheat bread.

Holtekjølén *et al.*, (2008) reported that the substitution of wheat flour with 40 % barley (*Hordeum vulgare* L.) flour caused a significant decrease in free phenolics (up to 23.5 %) during the baking whilst raising the

level of bound phenolics. Meanwhile, the actual assessed antioxidant activities have been comparatively stable throughout the baking process. Mäkinen and Arendt (2012) studied the effects of addition of oat malt in preparation of bread from wheat and barley malt and reported that substitution of oat malt substantially improved the loaf volume and nutritional quality of the developed bread. Škrbić *et al.*, (2009) documented that incorporation of hull-less barley and flakes to white and wholegrain wheat bread elevated the taste as well the intake capacity of selenium and  $\beta$ -glucan. Dhingra and Jood (2002) analyzed the consequences of the development composite bread with total fatted soy and defatted soy and barley flour in addition with wheat flour at 5 %, 10 %, 15 % and 20 % stages on sensory and nutritional quality. They discovered that replacement of barley flour with complete fat and defatted soy flour up to 15% triggered the important surge in proteins, total lysine, dietary fibre and  $\beta$ -glucan content. In the same way, the phytochemical regime, as well as the antioxidant potential of China steamed wheat bread (CSB) together with ingredients of flaxseed and barley hull was analyzed by Hao and Beta (2012). Their research exposed that CSB with barley hull improved the DPPH scavenging activity whilst the enrichment of wheat bread with 1 g of flaxseed hull extract, the oxygen radical absorbance capacity improved by 67.43 % in comparison to the control bread.

The effects of addition of wholegrain rye flour, barley flour, and oat flakes with refined wheat flour (replacing 60 %) were investigated by Koletta *et al.*, (2014). They revealed that nutritionally rich composite bread was developed with high in  $\beta$ -glucan, dietary fibres, and total phenolic content compared white wheat bread. Serpen *et al.*, (2012) analyzed the outcomes of multigrain (wheat, oat, rye, wheat bran, soybean, maize) recipes on total antioxidant potential in bread.

The outcomes of their research indicated that all multigrain recipes had greater furosine levels than wheat bread. Moreover, the total antioxidant potential was greater in ABTS assays for oat, rye and maize mixture and in DPPH assays for rye, oat and maize mixture while soybean and wheat bran had the highest value in both the cases. Angioloni and Collar (2011) prepared bread using a combination of oatmeal, rye, buck wheat and wheat flour. The total polyphenols content (TPC) was more in multigrain recipes with increasing replacement percentage by reducing wheat flour material i.e. from 592 mg/kg to 916 mg/kg. At the same time, they had higher antiradical activity than wheat bread. Ragaee *et al.*, (2011) confirmed the significance of wheat bread fortified with wholemeal wheat, rye, barley and their capability to increase antioxidants and dietary fibres. The assimilation of above flours amplified both the free and bound phenolic values with the elevated antioxidant activity of all the bread combinations.

In the past decades, several studies have been carried out on enrichment wheat bread with pseudo-cereals to enhance the nutritional and functional quality. Sanz-Penella *et al.*, (2013) researched the effects of mixing of whole amaranth (*Amaranthus cruentus* L.) flour with wheat flour up to 40 % level and analyzed its role as a potential bread-making ingredient. The enrichment of bread with amaranth flour impressively enhanced the protein, crude fibre, fat, and ash contents, simultaneously; enhancement of the phytates due to higher side enrichment inhibited the mineral bioavailability. So they proved that supplementation up to 10-20 % could produce a good quality bread with higher nutritional value. Vogrincic *et al.*, (2010) developed bread by supplementing Tartary buckwheat with wheat flour and they reported that the overall antioxidant capacity increased with increasing percentage of buckwheat. It was found from the results of the study carried out

by Lin *et al.*, (2009) that dehusked buckwheat substitution up to 15% of wheat bread claimed high antioxidant activity and nutrient density. In a similar study (Bojnanska *et al.*, 2009), the buckwheat wholegrain flour was added up to 30 % with wheat flour produced a quite satisfied product with higher consumer acceptability rating. The incorporation of wholegrain buckwheat (*Fagopyrum esculentum* L.) also enhanced the dough processing quality when added at different proportion. Stokić *et al.*, (2015) developed the buckwheat fortified wheat bread by replacing 50 % of wheat flour with buckwheat wholegrain. They discovered that the nutritional value and antioxidant capacity was fundamentally enhanced in the examination with the wheat bread (2.22 times higher aggregate dietary fibre and 4.29 times higher aggregate phenolics content). They additionally found that there was extensively lessening in total cholesterol and LDL-cholesterol, and also the proportion of LDL/HDL cholesterol. Verardo *et al.*, (2018) enriched bread with buckwheat flour at 10 %, 20 %, and 30 % levels and highlighted the differences between the phenolic composition of crust and crumb as well as flavonols and flavan-3-ols content. They showed that bread enriched with 30 % buckwheat flour increased the free and bound phenolics in crust whereas flavonols and flavan-3-ols content were higher in the crumb. The effect of the addition of pseudo-cereals like buckwheat, amaranth, and quinoa (*Chenopodium quinoa* L.) at 15 % and 30 % level on antioxidant activity and organoleptic properties were studied by Chlopicka *et al.*, (2012). They demonstrated that the supplementation increased the flavonoids content by 2-4 folds from control wheat bread. They also mentioned that buckwheat at elevated dosages increased the antioxidant activity to 2.36 fold and 3.64 fold evaluated by FRAP and DPPH assay respectively though fuse of amaranth, quinoa. A fascinating future trend has been evolved by

enrichment of wheat bread with flour from germinated (sprouted) cereals and pseudo-cereals. Khattak *et al.*, (2007) described that germinated seeds are nutritionally and functionally enhanced materials contrasted to the non-germinated seeds. Alvarez-Jubete *et al.*, (2010) documented the influence of sprouting of amaranth, quinoa, and wheat on polyphenol profile and antioxidant capacity. They revealed that among the greater part of all the sprouted seeds tried; buckwheat sprouts demonstrated the most astounding antioxidant activity. In a recent study, Marti *et al.*, (2018) developed a wheat bread with sprouted wheat flour at 15 %, 25 %, 33 %, 50 %, 75 %, and 100 % levels and evaluated the dough properties as well as baking performance apart from nutritional and sensory characteristics. They revealed that dough with 50 % sprouted wheat flour substitution gave a better baking performance with improved dough development.

### **Cookies enriched with various cereal grains**

Cookies are well-admired snack item consumed worldwide with a long life-span. In recent years, the quality of cookies has been improved into a manifold by integrating numerous items to the formulation such as vitamins, minerals, soy flour, wheat germ, milk powder and honey. This way, cookies can be used as a protein and fibre rich products. Apart from the nutritional enhancement, maintenance of sensory attributes for consumer acceptability is a key strategy for new product development (Rajiv and Soumy, 2015).

Barley grain is rich in many nutrients, such as dietary fibres (soluble and insoluble), B vitamins, minerals and phenolics which makes it as a popular ingredient in bakery items. Gupta *et al.*, (2011) developed cookies by mixing barley flour into wheat flour at different levels (10 %, 20 %, 30 %, and 40 %)

and studied their physico-chemical, functional and sensory properties.

They showed that all the formulation had higher fibre, mineral and protein contents as compared to the control bread. Additionally, the fortification of barley improved the colour as well as antioxidant properties and phenolics content. Sharma and Gujral (2014) prepared cookies by replacing white wheat flour with whole grain barley at various levels and evaluated the nutritional, functional properties and baking quality of developed cookies. They found that there was a considerable increment in antioxidant activity (AOA), total phenolic content (TPC), metal chelating activity (MCA), reducing power (RP) and total flavonoid content (TFC) with increasing barley proportion. However, the TPC and TFC value decreasing during the baking process.

A clinical research was carried out by offering cookies enriched with psyllium and oat bran to observe the plasma LDL cholesterol levels in different individuals from Northern Mexico (Romero *et al.*, 1998). It was determined from the research that there was a substantial decrease in the plasma LDL cholesterol levels among both normal and hypercholesterolemic individuals. Baumgartner *et al.*, (2018) enriched wheat cookies with dephytinized oat brans at 0 %, 7 %, 14 %, and 21 % levels and analyzed the physical, functional and sensory characteristics. They evidenced that fortification of cookies with dephytinized oat brans reduced the phytic acid content appreciably whilst enhancing the amount of dietary fibre, phenolics and antioxidant capacity compared to untreated oat bran.

**Table.1** Nutritional composition of some selected cereals (www.glnc.org.au)

Per 100g dry weight	Energy (kJ)	Protein (g)	Fat (g)	Saturated Fat (g)	Monounsaturated fat (g)	Polyunsaturated fat (g)	Carbohydrate (g)	Sugars (g)	Fibre (g)	Soluble fibre (g) <sup>§</sup>	Insoluble fibre (g) <sup>§</sup>	Cellulose (g) <sup>§</sup>	Folate (ug)	Niacin (mg)	Thiamin (mg)	Riboflavin (mg)	Iron (mg)	Magnesium (mg)	Zinc (mg)
Oats	1572	11.0	8.7	1.6	3.5	3.1	58.1	0.0	8.9	4.9	4.0	7	18	1.1	0.5	0.1	3.7	131	1.9
Brown Rice	1537	7.2	2.4	0.4	0.8	0.8	76.5	0.7	3.5	0.1	3.4	5	44	4.5	0.3	0.0	1.2	119	2.1
White Rice	1469	6.3	0.5	0.0	0.0	0.0	78.8	0.2	2.3	0.1	2.2	5	10	2.0	0.1	0.0	0.7	34	1.1
Millet	1489	11.1	4.2	0.7	0.8	2.1	63.3	0.4	8.5	-	-	5	85	4.7	0.4	0.3	3.0	114	1.7
Wheat	1278	13.4	1.4	0.2	0.2	0.6	60.1	0.96	12.0	1.6	10.5	4	51	1.9	0.3	0.1	11.0	110	5.6
Maize	1289	6.9	3.4	0.4	0.7	1.4	62.8	2.3	10.1	1.1	9.0	3	26	3.5	0.2	0.1	6.0	133	3.1
Barley	1186	9.2	1.7	0.3	0.2	0.7	58.1	3.26	11.4	5.5	5.2	18	50	5.2	0.2	0.1	9.9	122	3.2
Rye	1096	11.0	2.1	0.3	0.3	1.0	50.0	1.2	10.1	3.3	6.8	4	74	1.2	0.4	0.1	1.5	113	2.0
Triticale	1404	13.1	2.1	0.4	0.2	0.9	72.3*	-	-	-	-	1	73	1.4	0.4	0.1	2.6	130	3.5
Quinoa	1317	13.2	6.1	0.7	1.6	3.3	52.2	0.0	7.0	-	-	5	184	1.5	0.3	0.3	4.5	197	3.1
Amaranth	1551	13.6	7.0	1.5	1.7	2.8	58.5**	1.7	6.7	-	-	5	82	0.9	0.1	0.2	7.6	248	2.9
Buckwheat	1434	13.3	3.4	0.7	1.0	1.0	61.5**	-	10.0	-	-	4	30	7.0	0.1	0.4	2.2	231	2.4

\*Total carbohydrate by difference. Calculated as the difference between 100 and the weight in grams of (protein + fat + water + ash + alcohol) per 100g.

\*\*Available carbohydrate estimated by difference. Calculated as the difference between 100 and the weight in grams of (protein + fat + water + ash + alcohol + dietary fibre) per 100g.

Subsequently, substitution of oat flour with oat bran at 0 %, 30 %, 50 %, 70 %, and 100% was investigated by Duta and Culetu (2015) for its functional, rheological and wholesome properties. An overall acceptability of 5.6 was accomplished with highest  $\beta$ -glucan content (4.37% on dry weight basis) at 100% incorporation level of oat bran. However, cookies with more darkness and brittleness were produced having enhanced nutritional value at the higher level of supplementation.

Consequently, Arshad *et al.*, (2007) enriched the cookies by substituting wheat flour with a defatted wheat germ (DFWG) at proportions ranging from 0–25 % and its effect on functional and nutritional properties of cookies were analyzed. The DFWG had high total protein content i.e. up to 27.8 % (on dry weight basis) and also abundant in essential amino acids, particularly lysine (2.32 g/100 g). These properties of DFWG produced cookies with highly acceptable quality when fortified at most 15 % level as compared to control wheat flour cookies.

Inglett *et al.*, (2015) prepared sugar cookies using amaranth–oat composites in wheat flour to enhance the nutritional and physical characteristics of the multigrain cookies. They documented that addition of amaranth–oat composites produced cookies which were quite similar to wheat flour cookies in colour, flavour, and texture with enhanced nutritional value. They also showed that the composites had good viscoelastic properties and water holding capacity. Similarly, Altındağ *et al.*, (2015) prepared gluten-free cookie from buckwheat, rice, and corn flour with different proportions and evaluated the effect of transglutaminase (TG) on the cookies quality. The recipe containing 100 % buckwheat had higher protein and ash percentage but the buckwheat–corn cookies were higher in dietary fibre. Moreover, the addition of TG produced softer but higher brittle cookies with

enhanced moisture content and spread ratio contrast to cookies without TG. Likewise, Torbica *et al.*, (2012) formulated the gluten-free cookies from buckwheat and rice flour and evaluated the physicochemical and sensory properties. The cookies produced exhibit a gentle flavour and quite reasonable structural qualities. In addition, cookies supplemented with 20 % buckwheat expressed better sensory properties compared to control one.

### **Sweet bakery products (Cakes) enriched with various cereal grains**

The high fat and sugar content make the cakes a sweet bakery product. The basic materials for formulation of cakes are wheat flour, shortening, leavening agents, sugar, liquid (water, milk, or buttermilk), and eggs. The structural formation which supports these ingredients is important during cake preparation so that cakes of light and delicate should develop. Cakes are two kinds, such as foam type and shortened type (Martins *et al.*, 2017). In foam type cakes (angel food, sponge, chiffon), the foaming and aeration properties of eggs provide the structure and volume to the end product.

On the other hand, the structure of the cakes is developed from the fat-liquid emulsion formed during batter processing in case of shortened type cakes (pound cake, chocolate cake, etc.). The composition of recipes, the aeration and constancy of batters, and the baking and thermal setting processes are the essential parameters to produce good quality cakes with high volume, low crumb firmness, consistent crumb structure, reduced staling rate, and prolonged shelf-life. In this regard, the inclusion or supplementation of alternative flour to wheat flour reduced the staling rate triggering longer life-span (Jongsutjarittam and Charoenrein, 2013).



Sponge cakes from the polished flour of various hullless barley cultivars were prepared and compared against normal wheat flour cake with respect to rheological, nutritional, structural and sensory properties (Moza and Gujral, 2017). The aforementioned study exposed that the polished hullless barley sponge cake had high viscosity, stable batter and enhanced gelatinization time. The cakes had additionally higher soluble fibre ( $\beta$ -glucan) and arabinoxylans content extending from 3.4 % to 4.4 % and 0.7 % to 1.1 % respectively. Nevertheless, low protein and high non-starchy polysaccharide (NSP) content of barley flour enhanced the small-sized gas cell formation which amended the crumb structure.

Jongsutjarittam and Charoenrein, (2013) studied the freeze-thawed cake properties by adding 10-20 % waxy rice flour (WRF) into normal wheat flour (WF). They found that the incorporation of WRF in freeze-thawed cake remarkably lower the firmness and dense matrix with higher satisfactoriness than WF cake. The low amylase content and damaged waxy rice starch throughout the swollen wheat starch granules could be the possible cause of above happening.

Gularte *et al.*, (2012) studied the impact of the addition of various fibres like inulin and guar gum as soluble and oat fibre as insoluble constituent both in separate and combination form up to 20 % level to the rice flour in gluten-free layer cakes preparation. The oat fibre –inulin combinations produced cakes with increased specific volume and lighter crust and crumb structure. In contrast, oat–guar gum combinations developed cakes with improved batter consistency and crumb hardness. From above discussion, it was stated that the incorporation of fibres increased dietary fibres content in the diet with reduced slowly digestible starch and oat fibre–inulin combinations produced good

quality cakes. The diversity of fibre (whole wheat bran, oat bran, cellulose microcrystalline), particles size (50, 80, 250  $\mu$ m) and proportion of replacement (0 %, 12 %, 24 %, and 36 % level) on functional, rheological and sensory characteristics of batter and layer cake was assessed by Gómez *et al.*, (2010). They showed that the elasticity modulus ( $G'$ ) and viscous modulus ( $G''$ ) along with batter density increased with increased fibre size with a reduced dough behaviour index. Specifically, cake with bigger sized wheat bran fibre up to 20 % substitution produced the most floppy, elastic and yellow cakes with higher acceptability. However, microcrystalline cellulose added cakes produced similar cakes to that of control.

A multigrain approach for production of gluten-free cakes from cowpea, quinoa, proso millet, chickpeas, flaxseed and white rice flour was developed by Ávila *et al.*, (2017). They studied the nutritional, textural and sensory properties of the above developed multigrain cakes. They demonstrated that the protein content of the composites increased to 3 % whereas minerals like iron, magnesium and zinc increased to 26 %, 34.2 %, and 20 % of RDA when compared with regular cakes. Additionally, from sensory evaluation the cakes proved higher acceptability index (84 %) making it satiable gluten-free alternative.

### **Brittle bakery products (biscuits) enrichment with various cereal grains**

Biscuit is a small nutritive baked unleavened cake of crisp, flat, and sweet nature consumed globally. The important elements in biscuit recipes are similar to cake like wheat flour, shortening, sugar, and leavening agents. They have high fat and sugar contents. In view of water percentage in dough preparation, biscuits are categorized as soft (cookies) or hard (crackers). The soft dough is prepared with less water and reasonably high levels of

fat and sugar whereas hard dough contains high water and comparatively less fat and sugar. Furthermore, the soft dough has low extensibility and the hard dough is tough and extensible (Martins *et al.*, 2017).

In recent times, the demand for composite flour based health-oriented baked products such as biscuits, snacks or crackers are in high among consumer. Cukelj *et al.*, (2017) prepared biscuits from whole wheat, rye, oat, and barley mixed with flaxseed at 10 % (on weight basis) and measured the physicochemical, antioxidant, and tangible qualities along with oxidative stability during storage. They documented that proper combination of flaxseed with these flours produced acceptable biscuits with elevated phenolics. Moreover, the textural properties significantly influenced by the quality of cereal flour added and could be stored for three months at room temperature afterwards oxidative stability decreased.

In a study carried by Vujić *et al.*, (2015), either 30 % of the wheat flour was substituted with some wholesome flour from barley, buckwheat, oat, amaranth or soy or 15 % of wheat flour substituted by apple or oat fibre for the production of multigrain biscuits. The impact of the inclusion of all these flours on nutritional, functional and sensory properties of the end product was evaluated by the research group. They revealed that the fortification elevated the macronutrient content, dietary fibre content and protein content in the final product. However, the soy and amaranth inclusion generated products with reduced readily digestible starch (RDS) and total starch (TS) compared to control sample although oat and apple supplementation improved the glycemic response. Furthermore, all the formulations substantially increased the sensory acceptability in assessment to control wheat biscuit. Regarding fibre related nutrition

claims, Sudha *et al.*, (2007) developed biscuits by adding bran from wheat, rice, oat and barley to whole wheat flour dough and evaluated the rheological and biscuit making quality. They reported that the water absorption capacity of the bran mixed composite dough increased with increased level of substitution (0-40 %) along with reduced dough extensibility. In addition, highly favourable biscuits could be produced when whole wheat flour substituted with 30 % oat bran or 20 % barley bran. Similarly, Vilemejjane *et al.*, (2013) produced functional fibre rich biscuits from different fibres (oat bran, barley bran, and guar gum) and studied their effects on dough hydration as well sensory attributes. They showed that the dough consistency increased with total dietary fibre and reduced sugar content. A computer vision system approach was adopted by Lara *et al.*, (2011) in order to assess the physical, nutritional quality of corn biscuits during baking in real time and different oven temperatures. The colour, crust appearance and volume rise could be easily demarcated using the computer vision system which made the approach a useful tool.

Pseudo-cereals like buckwheat, amaranth and quinoa also fortified with biscuits and snacks to produce pseudo-cereal derived bakery products. Wójtowicz *et al.*, (2013) demonstrated the development of nutritionally enriched corn-buckwheat biscuit by supplementing to a level not higher than 30 % with good consumer acceptability. Baljeet *et al.*, (2010) effectively fused buckwheat flour into polished wheat flour biscuits not higher than 20 % to produced improved health quality biscuits with adequate tangible properties. Likewise, in another study by Filipčev *et al.*, (2011) claimed there was substantial upsurge in the nutritional quality (protein, dietary fibre, total polyphenols, antioxidant and chelating activity and macro and microelements) of wheat biscuits when

prepared with buckwheat at 10 %, 20 %, 30 %, and 40 % level. They also exhibited that the biscuits created by mixing of 20 %, and 30 % have remarkable acceptability score (6.71 and 6.20 respectively).

In last decades, individuals demand foodstuffs with better quality and health benefits plus minimally processed food created new challenges for the food industry. Baked products are widely consumed staple food among the greater part of population throughout the world and the most suitable carrier of dietary fibre and antioxidative compounds in the diet. So the fortification of bakery products with fibre rich cereals and pseudo-cereals has gotten restored enthusiasm due to resources other than cereal products being desired after and researched. In this sense, the paper has reviewed the recent advances in the above field and has documented the use of a diversified group of cereals and pseudocereals for production of nutritionally rich baked products. Several studies also emphasized on the functional and rheological behaviour of dough and batter and their interaction with the raw material, especially with fibre component. Many of the researchers had proposed that enrichment of cereals and pseudo-cereals and their fibres substantially enhanced the gluten network with improved shape, volume and texture of the end products.

In addition, the multigrain bakery products produced from various cereal grains exhibited better consumer acceptability throughout the world. Looking into above advantages, several food sectors have inspired and started this lucrative business over the last two decades. Therefore, inter-industry connections and research-oriented systems have to be addressed towards the development of health-oriented functional multigrain bakery products.

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