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A Review of Alternatives to Wheat Flour

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Abstract. For centuries, cereals have been major food stuffs used all around the world; because of that, there are many different kinds of breads produced from different types of flours. Despite the variety of flours available, there are still many challenges to produce ingredients which maximize nutrient components, and with which healthier breads and other products can be produced. As studies have shown, traditional wheat flour has some nutritional deficiencies (although this is a matter of perspective), which depend on the level of consumption. Additionally, gluten intolerance and Celiac disease are growing problems. The nutritional value of breads can be enhanced through the use of a variety of alternative flours. The objective of this study is to review and discuss alternatives to traditional wheat flour, with an emphasis on improved nutritional characteristics. Oat, for instance, has been used to improve the protein and fiber content of bread. Fortification of breads with soybean flour can also dramatically improve their protein quality. Barley, flaxseed, and rye flours can be used to increase the amount of dietary fiber in breads. Dietary fiber can reduce the risk of coronary heart disease, cancer, diabetes. Rye flour is recommended as an integral part of the diet as a source of biologically active substances. There are also other materials which can be used to add value to flour. One of them is DDGS, which is a co-product from the production of fuel ethanol from corn. By using alternative materials, traditional wheat flours can be fortified and their nutrient profiles enhanced.

Keywords. All-purpose flour, Alternative flour, Fortification, Wheat flour.

Introduction

Today, many countries are confronting problems such as malnutrition and micronutrient malnutrition (Pourafshar et al., 2010). More than two billion people in the world, especially children and women, suffer from deficiencies of various nutrients (Sudha and Leelavathi, 2008). Malnutrition can lead to underweight children, anemic mothers, diseases such as marasmus, beriberi, scurvy, kwashiorkor, etc. (Pourafshar et al., 2010). Food also supplies more than just energy and nutrients; it can help to reduce the risk of diseases such as heart disease, diabetes, osteoporosis, and cancer. The importance of a healthy diet cannot be stressed enough. However, the whole world is fighting with different forms of malnutrition and the lack of sufficient healthy foods which can be available for everyone. Thus to find solutions to these problems is of great importance.

One solution can be fortification of inexpensive food staples which are available all around the world. One of these sources is cereal. Cereals are cheap source of energy, and are consumed by almost everyone around the world. Fortification is the process by which nutrients are added to a food to improve its nutritional quality (Sudha and Leelavathi, 2008). Since many nutrient components of cereals are in the outer layers of grains and seeds, due to milling and refining these layers are often separated, and many of the nutrient components such as iron, zinc, vitamin A, fiber and other nutrients can be lost. So, to fortify cereal flours can be a great help in reducing malnutrition. Since wheat flour is the most consumed form of flour, it can be fortified with different materials, such as vitamins and minerals, but it can also be fortified with alternative flours or co-products. Different grains can be used, such as oat, barley, soybean, amaranth, rye, etc.

For example, oat can be used to improve the protein content of bread or to increase the soluble fiber level. Also, both oat and barley can enhance the β -glucan content of bread, which can have a significant effect on human health (Marriotti et al., 2006). Fortification of bread with soybean flour can improve the protein and fiber content of bread, and it is a good source of lecithin, vitamins, minerals and lignins, which may be beneficial in decreasing the risk of cardiovascular diseases and cancer (Mashayekh et al., 2008). Amaranth has twice the lysine content of wheat protein. It also has cholesterol-lowering properties attributable to its nutrient components; its fiber content is three times higher than that of wheat (Ayo, 2001). Studies have shown that intake of bread fortified with rye flour can result in stabilization of the iron statues in young women (Sudha, 2008). Because various sources are available which can be used to

fortify cereal-based foods, and can help to reduce malnutrition, especially micronutrient malnutrition, the objectives of this paper are to discuss traditional wheat flour, its shortcomings and potential alternatives that can be used to supply/fortify cereal-based foods.

Traditional Wheat Flour

Wheat is a major cereal crop in many parts of the world. It belongs to the *Triticum* family, of which there are many species; *T. aestivum* and *T. durum* are the most important commercially (McKevith, 2004). Wheat is divided into six classes based on different genetic characteristics. Some of these classes are Hard Red Winter, Hard Red Spring, Soft White, Soft Red, Durum and Hard White (Taylor et al., 2005). Wheat is well adapted to various environment and soil conditions, it is easy to cultivate and is highly yielding. Over the past 10 years, the world has produced nearly 576.3 million metric tons of wheat annually from approximately 218.2 million hectares of land. Wheat is used to produce different kind of foods, such as bread, pasta, noodles, pastry, breakfast cereals and baby foods. In order to produce these products, wheat must be processed into flour. Flour is produced from grinding and milling wheat kernels. There are different kinds of flours which are produced for specific purposes; for example, soft wheat flour is used for baking cake and pastry, hard wheat flour is used for bread, and all purpose flour is a blend of these two which is used to produce many types of the bakery goods (Hui et al., 2006).

All-purpose flour is a blend of hard and soft wheat flours. Each of these flours is used for a specific bakery product. Hard wheat flour is generally used to bake bread because of its high gluten levels. Soft wheat flour is a good choice for baked goods that do not need to rely upon high gluten content like pastries (Hillman, 2003). All-purpose flour, on the other hand, can be used to bake anything, it can be found in both bleached and unbleached forms. Bleached flour is better for making cookies, cakes and pastry, while unbleached flour is desirable in making yeast dough (Daley, 2001). Since the nutritional content of wheat grain is affected by the climate and seasonal changes, brands of all-purpose flours can vary in their nutrition contents over time as well.

Hard wheat flours are used in bread making because they form a strong gluten network in the dough which is necessary in production of bread. The gluten content of hard wheat flour or bread flour which is made from hard red wheat, can be between 12.5% and 14%. Bread flour can be white or whole wheat, bleached or unbleached, and can be also organic (Daley, 2001).

Nutritional Challenges

Although wheat flour comes in different forms, with various nutrient components and attributes, there are some deficiencies and challenges for which they should be fortified or enriched, or even replaced with other cereal grain flours. These problems can be deficiencies of some micronutrients, such as vitamins and minerals, or problems with the gluten of the wheat, which can cause various allergies and diseases in some people.

Naturally, wheat is a good source of vitamins such as vitamin B, vitamin E, as well as iron and zinc (Anonymous, 2010). But due to milling and refining, many of these nutrient components can be lost; therefore the final flour product will not be as nutritious. Wheat flour contains about 8-12% protein and has limited amounts of essential amino acids such as lysine which is an important nutrient for the body (Khetarpaul and Goyal, 2009). Another problem which is also caused by the milling process is the loss of dietary fiber. Dietary fiber can help reduce blood pressure; it can prevent and reduce heart disease, as well. But because the outer layer of the wheat grain is the source of fiber (Anjum et al., 2006), and this outer layer is removed by milling and processing the grain into flour, wheat flour would not be a good source of dietary fiber. Supplementing wheat flour with alternative flours would be one way to improve the nutrition of the ingredient.

Another important nutritional problem of wheat flour is the allergies it can cause in some people who are gluten intolerant. Gluten intolerance can cause many health problems. It can affect the skin, nervous system, immune system, teeth, and even behavior and mood. There are different types of gluten intolerance; the most important is Celiac disease (Wangen, 2009). Celiac is a genetic disease which is characterized by a sensitivity to certain sequences of amino acids found in the prolamin fraction of wheat and some other grains (Thompson et al., 2005). Because it is a genetically-based disease, there is an increase risk of 1 in 10 in families where Celiac disease already exists (Midhagen et al., 2004). When a person with such a disease consumes wheat, the mucosa of the small intestine is damaged, which causes malabsorption of nutrients (Thompson et al., 2005). People with Celiac disease are directed to have a gluten-free diet for the rest of their lives, which is often hard because gluten is a component found in many foods (Maher, 2008). So far, this is the only answer to this disease. Because one of the most important problems with wheat grain is the potential for gluten intolerance, it behooves scientists to look for solutions to replace this grain with other alternatives.

Alternative Flours

As Table 1 shows, there are many types of flours produced from different grains. Each of these flours has its own physical, chemical and nutritional properties. Here, some of these grains and flours will be discussed.

Almond

Prunus dulcis, also referred to as almond, is a species of tree native to the Middle East; it is also the name of the edible nut of this tree. Almond has many health benefits. These benefits include control of weight and diabetes (Richardson et al., 2009). Almond itself contains no carbohydrates, so it can be used to produce flour for cakes and cookies for patients suffering from diabetes. Almonds are very low in sodium and high in potassium (Richardson et al., 2009). It is also a good source of vitamins such as vitamin E, and also antioxidant components. Almond flour is gluten free so it can be used for gluten-sensitive people. Almond can be eaten on its own or can be used in breads, sweets, desserts, spreads, so it can be also a good replacement of peanut for those who have peanut allergy.

Amaranth

Amaranth (*Amaranthus caudatus*, *Amaranthus cruentus*, and *Amaranthus hypochondriacus*) is a nutritious grain as well as tasty leafy vegetable (National Research Council, 1984). Cultivation of amaranth dates as far back as 4000 B.C, when it was believed to have mystical qualities. Amaranth is a nutritious grain which contains high amounts of lysine; it has twice the lysine content of wheat protein (Pszczola, 1998). The high lysine in amaranth grain and flour can improve the protein quality of bread. Studies show amaranth flour can be used up to 15% in production of amaranth-wheat composite breads without any significant effect on physical and sensory qualities of the bread (Ayo, 2001). Amaranth is gluten-free, so it can be used in gluten-free products (Olexova et al, 2006).

Arrowroot

Arrowroot, *Maranta arundinacea*, is an herbaceous plant that grows to the height of 0.9 to 1.5 m (Erdman, 1984). Arrowroot plants are from rhizomes which used to be collected in St. Vincent, west India (Erdman, 1986). Arrowroot is used primarily as a source of food starch; this starch can be found in cylindrical rhizomes (Erdman, 1984). One of the products from this plant is arrowroot flour, which is not actually the product of one plant or root, but it is a combination of starches from several tropical roots. Arrowroot flour is gluten-free (Shepherd et al, 2006), and it

can be used as a thickener or an ingredient in biscuits and crackers. It can be used to replace corn starch or rice flour in pie and tart fillings as well (Daley, 2001).

Barley

There is evidence that the use of barley (*Hordeum vulgare*) dates back many thousands of years. For example, barley grains were processed and used to make bread in Israel 2000 years ago (Piperno et al., 2004). Barley is a resilient plant which is tolerant of a range of conditions. Barley flour can be used in soap, stew, beer, and bread making (Mckevith, 2004). Barley flour is milled from pearl barley. Because of its low gluten content, it can be used to replace up to 25% of the wheat flour for the production of yeast breads. It can add moisture and extend shelf life when it is added to the baked goods (Daley, 2001). Since plasma cholesterol concentration has an important role in cardiovascular diseases, it is important to have a diet which controls this. The amount and the nature of dietary fiber have a significant effect on the concentration of plasma cholesterol, and barley is a good source of dietary fiber so it can be a healthy source for those with cardiovascular problems, since it is capable of lowering plasma cholesterol (McIntosh et al., 1991).

Buckwheat

Buckwheat (*Fagopyrum esculentum*) is an important source of vitamins, dietary fiber, minerals and proteins. It is also a potentially good source of zinc as well (Ikeda, 1990). Buckwheat flour contains various components such as starch, lipids and enzymes (Kiyokaza, 1999), and available in dark or light varieties (Daley, 2001). This flour is widely consumed in countries such as Japan for the production of noodles, which is a traditional food (Namai, 1992). Buckwheat flour is gluten-free (Shepherd et al, 2006), and it also has healthy effects on the human body. Because of that, about 40 years ago, buckwheat was cultivated in the United States as an important commercial source of medicine (Couch et al., 1946).

Distillers Grains

Distillers dried grains (DDG) and distillers dried grains with solubles (DDGS) are co-products from the production of industrial fuel ethanol. Ethanol can be produced from corn grain using either the wet-milling process or the dry-milling process (Rosentrater and Muthukumarappan, 2006). There are three main products from dry grind ethanol production: ethanol, residual non-fermentable corn kernel components (which are used to produce DDG and DDGS), and carbon dioxide. Since these co-products are good source of nutrient components such as protein and fiber, they may be useful as a source of fortification for cereal-based foods. Typical nutrient

ranges are shown in Table 1. The fiber and the protein content of these co-products are relatively high, whereas the amount of non-starch carbohydrate is low. Because DDG and DDGS are based on corn, they are gluten free.

Maize

Zea Mays L, also referred to as corn, is a cheap form of starch and is a major energy source for animal feed (Mckevith, 2004). Maize, after wheat and rice, is the most important cereal grain in the world, and it provides nutrients for both humans and animals. Maize is also used to produce raw materials for the production of starch, oil, alcoholic beverages and more recently, fuel (FAO, 1992). As a food, maize can be used in a large number of products such as maize grits of different particle size, maize meal, maize flour or cornmeal, and flaking grits (FAO, 1992). Cornmeal, which is a flour ground from dried corn, can be made in yellow, white and even red varieties, and it is gluten-free (Olexova et al, 2006). Cornmeal absorbs liquids more slowly than wheat flour, so in the production of bread, the dough should be allowed to rest more than 5 to 10 min, so that liquid can be absorbed adequately (Daley, 2001).

Millet

Millet (*Pennisetum glaucum*) is a small-seeded annual grass that was first cultivated in Asia or Africa (Lorenz and Dilsaver, 1980). In North America, almost the entire crop is used as the main ingredient in bird seed; a small portion of the harvest is used for humans in the US, but in other countries millet is used as commonly as rice or barely (Daley, 2001). Nutritional content of millet is close to that of wheat, especially the protein content. Millet is also rich in B vitamins, especially niacin; it is also a good source of folic acid, calcium, iron, potassium and zinc. It is very easy to digest and is the least allergenic of any cereal or grain. There are different types of millet and millet-based products. For example, there are hulled millet grains which are used in a kind Russian food called Kasha. Ground millet can be used to form a thin pancake known as Kisra in Sudan (Bookwalter et al., 1987). Another product of millet is its flour which can be used in production of bread, pasta and cookies. Since the gluten content of millet is very low, it cannot be a complete replacement for wheat flour in production of yeast breads. It can be added to bread to reduce the amount of gluten and carbohydrate, because one of its properties is its sweet taste, so it can help to reduce the amount of sugar in the production of baked goods (www.wisegeek.com).

Oat

Oat (*Avena sativa*) can be grown in different climates; there are different kinds of species, with the spring or white oat the most common (Mckevith, 2004). Oat is a very healthy grain with high concentrations of proteins, lipids, vitamins, antioxidant, phenolic components, and minerals (Drzikova et al., 2005). The most important positive point in oat is the amount of dietary fiber. Since it is believed that dietary fiber has a positive effect in lowering blood cholesterol, oat can be a good source for this purpose. Soluble fiber can be found in many legumes, however it is the beta-glucan soluble fiber which has been shown to be most effective in lowering cholesterol. Beta-glucan can be found in the bran of oat (Jefferson, 2009). In most oat products, all three parts of the grain are used, so most oat products (such as oatmeal and oat flour) are as healthy as the grain itself. Oat flour is nothing more than very finely milled oat grain. Because of its low amount of gluten, oat flour should be used with wheat flour in production of yeast breads (Daley, 2001).

Potato

Potato (*Solanum tuberosum*) flour and potato starch are often used in baking products such as biscuits or cookies to add tenderness to those products and make a fine moist crumb. It also can be used as a thickener in soup, sauces, and other dishes. Potato flour is made from potatoes that have been cooked, dried and ground (Daley, 2001). In some countries, potato has a great role in the food industry and production of noodles. Since potato starch has a larger granule size in compare to the other starches, it can be used in production of different kinds of noodles in Japan. For example, since this flour is gluten-free (Shepherd et al, 2006), it can be used to produce noodles which are free of wheat flour and are called “glass noodles” because of their shiny and clear appearance after cooking (Takahiro et al., 2006).

Quinoa

Quinoa (*Chenopodium quinoa*) is a starchy annual herb which is mainly produced in the high lands of Peru and Bolivia (Morita et al., 2001). It contains large amounts of minerals, lipids and high quality protein, which contains essential amino acids such as lysine. The outer layer of quinoa seed contains an element named saponin, which is a bitter material that gives soapy taste to finished products if it remains during processing. Quinoa can lower the cholesterol level of blood. One of the products from this plant is quinoa flour which can be used in baked goods such as muffins, pancake, etc. (Daley, 2001). Quinoa flour is rarely allergenic because it is

gluten-free; substitution of quinoa flour for wheat flour could improve the balance of starch, protein and lipids, and can increase the loaf volume of bread (Morita et al., 2001).

Rice

Rice (*Oryza sativa*) is an important crop which is a staple food for many people globally. Rice can be used in breakfast cereals, or can be used as an ingredient in many recipes (Mckeivith, 2004). There are several varieties of rice which can be used in different recipes and products. Rice flour is one of the products which are simply rice that has been ground to a very fine powder; it is usually made from white rice, but can be made from brown varieties as well (Daley, 2001). Rice is gluten-free as well.

Rye

About 94% of the world's rye (*Secale cereale*) production is in Europe, of which 28% is consumed by humans. Rye is a good source of vitamins, minerals, vitamin E, and riboflavin. It contains both soluble and insoluble fiber and the amount of soluble fiber is even higher than that of the whole meal wheat and oatmeal. Rye can have a health benefit since the high amount of fiber can have a positive effect on lowering blood cholesterol and reducing heart diseases (Buttriss, 2006). Since rye is a good source of biologically active substances such as antioxidants, it is recommended as a part of the diet (Zielinski et al., 2007). Rye flour can be produced as dark or whole rye flour. Dark flour retains much more of the proteins, vitamins and minerals (Daley, 2001). Rye flour contains some gluten, but the amount of gluten is much lower compared to wheat, so the bread made with rye is dense, heavy, and damp. Rye flour's strong flavor makes it unsuitable for most desserts, but still it is used in some traditional dishes and recipes (Daley, 2001).

Soybean

Soybean (*Glycine max*) is a healthy grain with many nutrient components. It is high in iron, calcium and zinc (Issakhan et al., 2005). One of the major components in this grain is soy protein. If soy protein is consumed at the recommended level every day, it has enough essential amino acids to meet human nutritional requirements, since it is equivalent to animal protein in quality (FAO/WHO/UNU, 1985). Consumption of soy protein can reduce the risk of cardiovascular diseases since it lowers total and LDL blood cholesterol. Soy protein is produced from raw whole soybeans and in order to increase the availability of protein, the lipids and indigestible components are often removed (Erdman, 2000). Soy flour is one of the products produced from milling soybeans. Soy flour can be found in two different forms, defatted soy flour

and full-fat soy flour (Kwolek et al., 1971). Since soy flour does not behave as conventional flour in baking, it should be blended with other flours. Soy flour is gluten-free (Shepherd et al, 2006) and can be used as a thickener for sauce or it can be used in sweet confections, candies, etc. (Daley, 2001).

Spelt

Triticum spelta, also known as spelt, was originally grown in Iran around 5000 to 6000 B.C. Spelt is very similar to wheat in appearance; however it has a tougher husk than wheat. Spelt flour can replace whole wheat flour or whole grain flour in foods such as bread and pasta (Jegtvig, 2008). Since the nutrient (and gluten) content of spelt is close to that of wheat, it is not suitable for people with Celiac disease.

Tapioca

Tapioca flour is obtained from the root of the cassava plant (*Manihot esculenta*). Mostly it is used as a thickening agent because it is a starchy substance. Tapioca flakes can be used in health and natural food stores. Tapioca flour or tapioca starch is a finely ground dried starch which is used as a thickener for sauces, soups, puddings, etc., and it is gluten-free (Shepherd, 2006). It also can be used instead of rice flour, cornstarch or potato flour (Daley, 2001).

As illustrated by both Table 1 and the above discussions, all of these flours could be a good source of nutrient components, but since most of them are not high in gluten, they cannot completely replace wheat flour in all baked goods, such as yeast breads, where gluten plays an important role. Overall, because of their positive effects on health and prevention of different diseases, especially cardiovascular diseases, they can be used in baked products, partially or completely, depending on the specific product and its characteristics.

Conclusions

Cereals are some of the most consumed foods around the world. Cereals are an inexpensive source of energy and nutrients, and because of their moderate prices many people can afford to buy them. But the problem with most baked products, especially those in which wheat flour is used, is that many of the nutrients, such as minerals, vitamins, and fiber can be lost due to milling. To help people to receive more nutrient components and to reduce certain diseases and problems (such as cardiovascular diseases, allergies, cancer, and malnutrition), it is important to improve the nutrient profiles of cereal products. Fortification of flours and their products is one way to achieve that goal. Alternative grains can be used as well. These cereal grains have many nutritional compounds and potential health benefits. Another source of fortification can be

co-products from cereal grain processing, such as DDGS, which is high in protein and fiber. Most of these fortification sources are relatively inexpensive, so improved or altered flours is an effective way for people to consume more nutritious food globally.

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Table 1. Nutrient compositions of different flours (from various market sources).

Type of Flour	Protein (%)	Fat (%)	Carbohydrate (%)	Fiber (%)
All-purpose flour	10.32	2	32	14
Amaranth	12.5-17.6	6.3-8.1	62.17-64	3.6-4.2
Arrowroot	0.3	0.1	88.15	3.4
Almond	6	14	6	3
Barley	11.3	1.9	85.4	0.8
Buckwheat	4	1	21	4
Corn	2	1	22	4
DDG ¹	27.0 – 29.2	7.6 – 14.0	46.5	31.5 – 47.3
DDGS ¹	26.8 – 33.7	3.5 – 12.8	39.2 – 61.9	25.0 – 51.3
Millet	3	1	22	4
Oat	4	2	16	3
Pea	4	1	9	4
Potato	6.9	0.34	83.8	5.9
Quinoa	4	2	21	4
Rice	3	1	8	4
Rye	4	1	21	7
Soy	7	4.5	9	4
Spelt	4	1	22	4
Tapioca	0	0	26	0
White Rice	5.95	1.42	80.13	2.4
Whole Wheat	13.7	1.87	72.57	12.27

1. Rosentrater and Muthukumarappan, 2006