# Biscuits: A Substitution of Wheat Flour with Purple Rice Flour

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**Abstract.** Biscuits are excellent snacks with a long shelf life. However, they are also high-energy foods so there is a great need to improve their nutrient value. Many substitutions of composite flours for wheat flour have been studied in order to reduce their potential negative impact on human health. Whole purple rice flour is a novel flour with high antioxidant contents and dietary fiber. However, the partial replacement of wheat flour with purple rice flour can affect the physicochemical properties and consumer preferences of biscuits. Therefore, producing a new product to meet consumer demands presents many challenges. Lipid oxidation is always a problem during extended storage. Inhibition of lipid oxidation in biscuits leading to rancidity and loss of nutritional value is also an important consideration for these biscuits. There is a high demand to use natural antioxidants in foods to enhance the shelf life of biscuits. Hence the scope of replacing wheat flour with purple rice flour in biscuit production needs further study.

**Keywords:** Biscuits; purple rice flour; consumer preference; texture; antioxidants; color

## 1 Introduction

Bakery products are the most popular processed food items in the world [1]. Of these, biscuits represent the largest category of snack foods among bakery products because they are made from simple, cheap and easily available raw materials. They are widely consumed because they have a very acceptable taste and their low water activity allows a long shelf life [2]. Unfortunately, biscuits, because they are generally made from wheat flour and fat, are also high-energy easily digestible foods. This can negatively impact on health if they are consumed regularly, particularly in excess [1]. Marketing forecasts suggest that global biscuit sales will grow significantly by 2020, and healthy biscuits are expected to perform well in this sector [3]. Fortification of food products plays an important role in increasing health-promoting functional components in bakery products to provide additional benefits to meet consumers' demands [4]. There is also a good possibility of improving the overall nutritional contribution of biscuits by reducing the content of wheat flour. Researchers in developing countries have begun to evaluate the possibility of using locally-available products, such as soybean, plantain and amaranth flours, as substitutes for wheat flour [2,5]. These flours provide a useful means of improving the nutritional values of the protein and bioactive compounds in the biscuits through the incorporation of less expensive non-wheat flours. Many researchers have used alternative, locally-grown crops in place of wheat flour in biscuits in order to decrease the costs associated with using imported wheat [6-8].

Tasty and healthy foods depend on the addition of high quality ingredients [9], and biscuits can easily be fortified to manufacture healthier products. The food industry is facing the challenge of developing new food products with special health-enhancing characteristics. Determining the physical and chemical properties of a new product is important in assisting with the development process. The basic determinations of moisture, protein, fat, ash and carbohydrates give an indication of the nutritive value of a product but the values of these change depending on the mixture of raw materials used to make the product [10]. Physical and textural characteristics of biscuits, especially hardness, are important characteristics for consumer acceptance [10]. Changes in the nutritional composition and textural properties of biscuits using fortified flour as a replacement for wheat flour have been studied [11-15]. Different materials and methods led to important physicochemical changes in the final product. Klunklin and Savage [15] showed that replacing refined wheat flour with purple rice flour changed the chemical composition, physical characteristics, functional properties and the sensory evaluation of the final product.

 

One of the biggest challenges in creating a new food product is predicting how it will be accepted by consumers. The physicochemical changes of new products are also important factors for consumer acceptance of a new product [3,9]. The color of a food is a very important quality attribute that is evaluated even before a food is tasted [16]. Food color is related to the many physicochemical changes that occur during food processing. Food processors use color measurements of food products as an indirect measurement of other quality attributes, such as antioxidants, and color correlates well with other physicochemical properties. However, many different cereals have been added to wheat flour biscuits, but the addition of purple rice flour has not yet been fully investigated.

## 2 Biscuits

Although, biscuits vary in their shapes, sizes and composition, the three main ingredients are always flour, sugar and fat (butter or vegetable shortenings) [17]. Commercial biscuits normally constitute 50% of calories from fat and carbohydrates, with over 400 calories per 100 g in plain biscuits [18]. Biscuits broadly form into two groups, hard and soft biscuits, depending on their ingredient mix [19]. Commercial biscuits are prepared from refined wheat flour that consists mainly of carbohydrate as starch (70–75%), water (13-15%), protein (10-12%), fat 1-2%, together with some fiber, ash and minerals [20]. The protein in wheat flour is mainly gluten, which is made up of two major protein fractions - monomeric gliadins and polymeric glutenins. Gluten proteins are an important element in bakery products and are responsible for the elasticity, cohesiveness and viscosity characteristics of the dough. The percentage of protein in wheat flour affects the flour strength [20]. Therefore, replacing wheat flour with another type of flour will change the amount of gluten protein, which will then affect dough formation [21].

Sugar is commonly used as a sweetener, but it also serves various functional properties in food processing, such as the flavor, color and texture of the dough [22]. A complex series of browning reactions involving sugar occur above 160°C that cause the baked products to develop a brown crust. This phenomenon is known as a Maillard reaction [22]. In baked biscuits, sugar binding with water molecules prevents the growth of microorganisms and improves the shelf life [22]. Fats are the principal ingredients that contribute to the general appearance of the product and raise the quality of the biscuits, the mouthfeel and the texture by interacting with other ingredients [23,24]. Fats reduce the abrasive effect of flour and sugar during mixing and processing. In addition, fats also enhance aeration giving an increased volume and open texture to create a softer mouthfeel [24]. The secondary function of fats in biscuits is to create the flavor of the finished product. Bakery fats (particularly butter), which contain about 80% fat, are ingredients in the dough that have the most dominant effect on the final flavor. In addition, fats can extend the shelf life of products by masking or slowing the staling process as fats in the crust slow moisture migration into the biscuit [23].

### 2.1 Biscuit Production

The four main processes to make biscuits are mixing, cutting, baking and packing [25]. Biscuit production needs precise preparation to make a successful product [26]. The ingredients are mixed to form a dough using mixers that are either operated manually or using a pre-set mixing program [27]. As the dough is mixed, the protein molecules form long strands of gluten resulting in an elastic web, which, essentially, controls the quality of wheat flour-based products [21]. Once the dough is mixed, it is then made into different shape and sizes. This process leads to an increase in the stress on the gluten structure.

Baking is a very important process to achieve good quality biscuits. This process transforms the physical and chemical characteristics of the dough when baked in an oven [28], where the temperature and time will be accurately controlled. The oven temperature affects the moisture loss during baking, which plays an important role in achieving a good texture and the structure of the biscuits [27]. Since gluten needs a large amount of water to form and develop a gluten web as well as hydrate the starch granules [24]. The structure of the biscuits is formed, and free water evaporated when gluten and starch have been sufficiently hydrated. The evaporation starts from the dough surface, achieving about a 2-5% moisture content in the final products [28]. Baking also alters the color of the biscuit surface; namely, the browning process. There are three main browning processes: caramelization of sugars, dextrinization of starch and the Maillard reaction in reducing sugars and amino acids, associated with the biscuit production. These processes occur when the biscuit surface is already dry and the temperature is high (above 100°C). Coloring of the biscuits takes place in the final stage of the baking process [27]. Packaging is used as a barrier to protect the biscuits and prevent the deterioration following absorption of moisture from the air. Moreover, biscuits can be protected from cracking and being broken by choosing the right packaging materials. Selecting and handling the materials used to pack the biscuits are crucial for the life and qualities of the final products [27].

Biscuit production changes in both the chemical and physical characteristics, which result in the structure, texture and color changes in the biscuits [19]. Overall, the characteristics of high quality biscuits also depend on the type and proportions of the ingredients.

### 2.2 Fortification of Biscuits

Biscuits can hardly be regarded as a healthy snack because they usually contain high levels of rapidly digested carbohydrate, high fat, generally low levels of fiber and only modest amounts of protein [5,29]. Several studies have used blended flours or composite flours to produce biscuits [2,7,11,17,26,29-35]. There have also been a number of attempts to improve their nutritional characteristics by partially replacing the wheat flour with non-wheat ingredients in the production of biscuits. Replacing wheat flour with different types of flour mostly affects their nutritional values and physical characteristics, such as hardness and spread ratio as well as color parameters, which can be observed in Table 1. Brown rice flour has been used to improve the nutritive values of biscuits together and increase the overall acceptability of the fortified biscuit [36].

In consideration of the development of a new product, it is important to use locally sourced ingredients, as the tastes would then be appreciated by the ethnic groups the products were intended for [37]. The texture, flavor and appearance of biscuits are major attributes that affect biscuit acceptability [38]. Moreover, many studies have investigated the properties of gluten-free biscuits using different types of rice flours, such as white rice flour with buckwheat flour [38], waxy rice flour [39], brown rice flour [33,36,40] and a composite rice flour, together with green gram flour and potato flour [41], or broken rice mixed with cocoyam flour [25]. Unfortunately, rice protein cannot generate a viscoelastic network like gluten in wheat, which retains carbon dioxide during biscuit dough fermentation. Therefore, the addition of rice to a biscuit mix can have a significant effect on the textural qualities of the cooked biscuit.

Recently, products with high protein and fiber contents are more commonly chosen by consumers to reduce the risk of diabetes and obesity. The protein enrichment of biscuits can be achieved by adding different kinds of ingredients, such as Nile tilapia fish bones [42], soya protein [43,44], and defatted green-lipped mussel powder [45,46]. The development of a high protein containing biscuit is a worthwhile challenge when the overall nutritional status of underprivileged sections of the population is considered. Dietary fiber in the bran and germ of cereal grains has been added to biscuit formulations that originally contained almost no dietary fiber in the original recipe [33,47,48]. Substitution of purple rice flour for wheat flour will not only increase the dietary fiber and bioactive contents, but it is also a cheaper raw material [49].

Consumers are always concerned about the fat content of biscuits. In recent years, an enormous amount of research work has been carried out to study the possibility of adding healthy fats to biscuits without changing the flavor and texture of the final products. Fat and sugar replacement using dietary fiber, such as inulin, β-glucan, potato fiber, mango peel, rice bran, wheat bran, arabinoxylan and complex oligosaccharides, have been added to increase the nutritional quality of biscuits [50-52]. Garden cress seed oil has been used to enrich the α-linolenic acid content of biscuits. It was added to produce ω-3 fatty acid-rich biscuits in order to increase antioxidant properties of the product [53]. Grape marc extracts have been added to biscuits and this has increased their antioxidant activity and phenolic contents compared to control biscuits made using wheat flour [54]. The overall flavor and cross-sectional structure and appearances of the biscuits were improved by these additions.

Since biscuits are easy to consume as a snack or dessert with long shelf life when efficiently packed, many food manufacturers are interested in developing new and nutritional biscuits. Commercial bakery products generally contain high levels of carbohydrates and fats with small amounts of protein and fiber.

 

Modifying the composition of biscuits is a way to increase the nutritional value of the product, such as by adding rice to increase protein and fiber content of final product.

**Table 1.** Effects of replacing wheat flour on physicochemical characteristics and antioxidant properties of wheat-based biscuits

| Types of flour | Replacing wheat flour (%) | Outcomes | References |
|---|---|---|---|
| Barley | 10, 20, 30 and 40 | -decreased protein content<br>-increased darkness<br>-decreased spread ratio | [116] |
| | 25, 50 and 75 | -increased darkness<br>-decreased spread ratio<br>-increased antioxidant activity | [117] |
| Beniseed and unripe plantain | 10, 20, 30 and 40 of beniseed with 10% unripe plantain flour | -increased spread ratio<br>-increased protein content | [6] |
| Chestnut | 20, 40 and 60 | -increased fiber content<br>-increased hardness<br>-increased darkness<br>-decreased spread ratio | [14] |
| Chia seeds | 5, 10, 15 and 20 | -increased darkness<br>-increased polyphenols<br>-no change in hardness | [118] |
| Chick pea | 5, 10 and 15 | -decreased spread ratio<br>-decreased water absorption | [119] |
| | 20, 40, 60, and 80 | -increased darkness<br>-no change in spread ratio<br>-increased hardness | [120] |
| Defatted groundnut | 5, 10, 15, 20, 25 and 30 | -improved protein content | [121] |
| Defatted maize germ | 5, 10, 15, 20 and 25 | -decreased spread ratio<br>-increased protein content<br>-increased darkness | [123] |
| Defatted soy | 28.6, 50 and 71.4 | -increased protein and fiber contents<br>-increased lysine content | [124] |
| Flaxseed | 6, 12 and 18 | -increased darkness<br>-decreased height | [30] |
| | 20 with multigrain flour | -increased bioactive compounds<br>-increased spread ratio | [3] |
| | 5, 10, 15, 20, 25 and 30 | -increased protein content<br>-increased antioxidant activity<br>-increased darkness<br>-increased spread ratio | [62] |
| Fluted pumpkin seeds | 5, 10, 15, 20 and 25 | -increased protein and moisture content<br>-decreased spread ratio<br>-decreased hardness | [12] |
| Green gram flour | 10, 20, 30, 40 and 50 | -increased protein content with decreasing fat content<br>-increased darkness<br>-decreased spread ratio | [125] |
| Jering seeds | 5, 10, 15 and 20 | -increased protein and fiber content<br>-decreased fat content<br>-decreased spread ratio<br>-increased hardness | [48] |
| Lupin | 5, 10 and 15 | -decreased spread ratio<br>-decreased water absorption | [119] |

 

| Types of flour | Replacing wheat flour (%) | Outcomes | References |
|---|---|---|---|
| | 10, 20, 30, 40 and 50 | -increased protein and moisture content<br>-decreased spread ratio<br>-increased hardness<br>-increased darkness | [13] |
| Lupin (germinated) | 10, 20, 30, 40 and 50 | -increased protein and fiber contents<br>-decreased spread ratio | [126] |
| Mahaleb cherry seeds | 1, 2, 3 and 4 | -increased darkness<br>-increased hardness<br>-increased moisture content<br>-increased antioxidant capacity | [8] |
| Navy bean | 10, 20 and 30 | -increased protein content | [127] |
| Oak fruit | 15, 30 and 45 | -decreased moisture content<br>-increased antioxidant activity | [128] |
| Papaya pulp | 15, 30 and 50 | -increased crude fiber content<br>-increased antioxidant capacity<br>-increased hardness | [47] |
| Pigeon pea | 25, 50 and 75 | -decreased sugar content<br>-slow the hydrolysis of starch | [35] |
| Potato | 10, 20 and 30 | -decreased spread ratio<br>-decreased carbohydrate | [129] |
| Purple rice | 25, 50 and 75 | -increased darkness<br>-increased antioxidant properties<br>-increased spread ratio | [15] |
| Quinoa | 15, 30, 45, 60 and 90 | -increased darkness<br>-no changes in texture properties | [130] |
| Sorghum | 5, 10, 15 and 20 | -not significantly changed in physical characteristics (thickness, width and spread ratio)<br>-decreased moisture content | [131] |
| | 30, 50 and 70 | -increased spread ratio | [132] |
| Soy bean | 5, 10 and 15 | -decreased spread ratio<br>-increased water absorption | [119] |
| | 10, 15 and 20 | -decreased moisture content<br>-increased protein and fiber contents | [133] |
| Taro | 51% and 100 | -lowed spread ratio<br>-soften the texture of the biscuits | [134] |
| | 5, 10, 15, 20, 25 and 30 | -increased protein<br>-increased elasticity | [135] |
| Unripe banana | 15, 30 and 50 | -increased fiber content<br>-increased slowly digested starch | [136] |
| Water chestnut | 60, 70, 80 and 90 | -increased water absorption<br>-decreased spread ratio | [137] |

## 3 Purple Rice

Rice (*Oryza sativa* L.) is one of the most widely eaten cereal grains in Asia [55]. In Thailand, red, purple and black rice is widely grown in different locations [56], which results in many different pigmentation phenotypes being observed throughout the country [57]. Many of the pigmented rice cultivars are reported to contain higher levels of antioxidants than white rice [15,36,49,58]. This can be classified depending on anthocyanin and proanthocyanidin compounds in the aleurone layer of rice grain [59].

Purple rice, also known as forbidden rice, has been grown in China since the Tang and Sung Dynasties [60]. Purple rice was served only to Chinese royalty but the emperors would share purple rice with warriors who were about to go into battle due to its perceived medicinal properties [58]. As well as China, this rice has a long history in South Asia, including Indonesia, India and Thailand. Purple rice is a glutinous, whole grain containing a high amylopectin content [57,61], which can be grown in many Asian countries, such as Laos, China, Indonesia, Malaysia, Japan, Korea, Philippines and Thailand [59]. Purple rice (var. Sanpatong) is widely grown in Northern Thailand and is becoming a popular crop because of its improved taste compared to white rice [15,49,62]. However, the price of purple rice is five times higher than normal white rice due to its lower productivity. Nowadays, the demand for pigmented rice consumption is increasing rapidly throughout European countries and also in the USA because of its high nutritive value and antioxidant properties [53,57,58,63].

### 3.1 Bioactive Components in Purple Rice

Purple rice has several nutritional advantages over white rice, such as higher protein, vitamin and mineral contents; for example, Fe, Zn, Mn and P [58]. The bran layer of this rice has a high level of antioxidant compounds, mainly phenolic acids, flavonoids, anthocyanins and oryzanols [60,64-66]. Purple rice has been shown to have significantly more anthocyanin contents than pigmented corn, wheat and barley [15,49,56,60]. The study of the anthocyanin profile by spectroscopy assay showed that extracted purple rice has four active components; cyanidin-3-O-glucoside (C3G), peonidin-3-O-glucoside, cyanidin-3,5-diglucoside, and cyanidin-3-glucoside [56,58]. The predominant anthocyanins are C3G (around 92% of total anthocyanins) and peonidin-3-O-glucoside [58,60]. Many researchers have reported that C3G contributed the highest antioxidant activity of raw and purple rice bran [49,56,59,60,62,66-69]. However, only a few researchers have studied the phytochemical and antioxidant activities of different cultivars of purple rice flour, as shown in Table 2.

**Table 2.** Antioxidant compounds (total phenolic compounds, TPC and cyanidin-3-O-glucoside, C3G) and antioxidant activity (DPPH and ABTS assays) of raw purple rice

| Cultivars | Origins | TPC (mg GAE /100 g DW) | C3G (kg /g DW) | DPPH (mmol TEAC/100 g DW) | ABTS (mmol TEAC/100 g DW) | References |
|---|---|---|---|---|---|---|
| Unknown | China | 492.0 | - | 22.7 | - | [61] |
| | China | 709.3 | - | 23.6 | 3.1 | [65] |
| | Italy | 282.2 | - | 10.0 | 2.2 | [65] |
| | Japan | 252.6 | - | 10.7 | 1.8 | [65] |
| | Laos | 504.6 | - | 16.8 | 3.1 | [65] |
| | Thailand | 458.3 | - | 1.8 | 2.6 | [65] |
| D Youzinuo 161 | China | 41.5 | 12.0 | 1.6 | 3.2 | [66] |
| Heimi No. 1 | China | 38.6 | 83.3 | 1.3 | 2.7 | [66] |
| Heixiangnuo No. 3 | China | 51.4 | 226.7 | 2.01 | 4.4 | [66] |
| Heinuomi | China | 62.6 | 683.7 | 2.7 | 5.8 | [66] |
| Heimi 2420 | China | 54.8 | 1106.0 | 1.6 | 4.7 | [66] |
| Heiyounian | China | 643.0 | 0.3 | - | - | [137] |
| Sintoheugmi | Korea | 356.3 | 0.018 | - | - | [81] |
| Sinnongheugchal | Korea | 179.5 | 0.0009 | - | - | [81] |
| Luem Pua | Thailand | 75.5 | 17.8 | 7.2 | 8.5 | [59] |
| Mali Nil Surin No. 6 | Thailand | 492.0 | 49.0 | - | 2.8 | [68] |
| Niew Dum | Thailand | 336.7 | 137.4 | 5.0 | - | [67] |
| Riceberry | Thailand | 116.0 | 37 | 130.0 | - | [69] |
| Sanpatong | Thailand | 318.3 | 492.6 | 10.3 | 4.7 | [49] |

### 3.2 Analytical Methods

It is important to determine the antioxidant contents of food products, to identify their effectiveness for preventing or delaying lipid oxidation in the cooked product. Ghani et al. [70] and Tan and Lim [71] have reviewed many different antioxidant assays to evaluate the antioxidant compounds in foods, such as total phenolic compounds, anthocyanin and flavonoids [71]. Anthocyanin and total phenolic compounds (TPC) of purple rice have been shown to have high antioxidant capacities using the oxygen radical absorbing capacity method [56,72]. However, the recommended assay for determination of antioxidant capacity was to use 2,2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenging assay and 2,2′ -azino-bis (3-ethylbenzthiazoline-6-sulfonic acid) (ABTS), since they were considered to be simple, accurate and economic assays [73].

### 3.3 Use of Purple Rice in Food Products

The development of rice production to enhance human health benefits is very attractive because rice is economically a very important crop for Asian countries. Apart from daily consumption as cooked rice grains, purple rice is also used to produce desserts and snacks in China and Thailand, such as coconut black rice pudding [60,74]. Food manufacturers are beginning to develop high quality good-tasting food using the unpolished rice grain, which includes the germ, bran, and endosperm [60]. The whole grain contains phenolic acids (ferulic, coumaric and caffeic acids) and free phenolic compounds (i.e. gallic acid). Kim et al. [75] confirmed that purple rice powders were able to enhance the anthocyanin and overall antioxidant qualities of the traditional Korean rice wine (takju). These phenolic acids and anthocyanin compounds are thought to reduce the risk of colon cancer when eaten in moderate amounts [65]. Pigments extracted from purple rice bran can also be used as alternative of artificial colorants for foods and beverages [76]. These pigments have been used to increase the functional components of various snacks, cakes and breakfast cereals [60].

## 4 Application of Rice and Purple Rice Flours

### 4.1 Rice Flour

Rice flour is gluten free and useful as alternative to wheat flour, which contains gluten that can cause celiac disease in susceptible individuals [77]. Rice flour is not widely used in bakery products since it has no protein structure to hold the carbon dioxide in the product during baking [78]. Other proteins are added as foaming agents in bakery products to improve the elasticity of the products, enhance the taste and help develop a gelatinization structure [79, 80]. Therefore, rice flour has been used, together with proteins, as ingredients to make gluten-free crackers [79], brown rice flour is used to make traditional Korean rice cakes [77] and riceberry flour can also be used to replace wheat flour in noodles [80]. Nevertheless, this is not so important in biscuit-type products as they are not required to rise in the same way as bread. Broken rice blend flour is also used to produce biscuits that are baked in a microwave [81]. Rice flour with its small particle size also needs to absorb more water during food processing compared to wheat flour [80]; this means the production of soft and smooth products, such as rice noodles, fermented condiments (miso and mirin), congee need more care taken during their production [82].

### 4.2 Purple Rice Flour

Finely milled and graded purple rice flour has been used in many traditional desserts made in Thailand, Indonesia and China. It is also used as a gelling or thickening agent in many cakes and breads due to its high viscosity [59,83]. The nutritional properties of purple rice flours in various cultivars have been investigated (Table 3). Recently, Klunklin and Savage [49] reported that refined wheat flour contained more starch and protein contents than purple rice flour which, in contrast, contained higher total fiber contents. Purple rice flour was used to develop cake properties, such as firmness, gumminess and chewiness, without changing sensory quality characteristics [83]. Jung et al. [84] reported that the supplementation of 20% purple rice flour for wheat flour did not show any significant differences in the sensory characteristics of the bread. Purple rice flour has also been used as a base ingredient for making pasta [85] or partially used to replace wheat flour to make biscuits. Their functional properties, such as foaming, bulk density, swelling power and lower gelation concentration of the flour, affect the texture characteristic of the biscuits and, generally, without changing the overall taste [15,49].

 

**Table 3.** Nutritional compositions of Thai purple rice flour compared with rice berry flour, white rice flour and refined wheat flour

| Nutritional properties (% DW basis) | Purple rice flour | | | Riceberry flour | White rice flour | Refined |
|---|---|---|---|---|---|---|
| | (var. Sanpatong) [49] | (var. Niew Dum) [68] | (var. Kam Doi Saket) [138] | (var. Khao Dawk Mali 105) [74] | (var. Unknown) [36] | wheat flour [49] |
| Moisture content | 11.6 | 12.0 | <14% | 9.6 | 5.5 | 12.5 |
| Ash | 1.1 | 1.48 | 1.3 | 1.1 | 1.0 | 0.9 |
| Total fat | 2.8 | 3.7 | 1.8 | 3.6 | 8.1 | 2.0 |
| Crude protein | 13.0 | 10.9 | 6.6 | 7.5 | 13.2 | 15.4 |
| Total dietary fiber | 5.6 | 3.4 | 2.5 | 1.66 | - | 2.3 |
| Total carbohydrate | 71.5 | 71.9 | 87.8 | 77.1 | 72.2 | 69.2 |

## 5 Evaluation of Fortified Biscuits

One of the most important concerns of pilot scale production is to make a product that can be efficiently made in a full-scale commercial facility. It is important that the final product can be made consistently with the same appearance, texture, flavor, color and shelf life as the experimental test products. It is important that a new product containing multiple, processed ingredients has a consistent quality. The quality of foods is difficult to define precisely; however, all characteristics need to be measured, as these are significant in the fortification of the quality of new products and to make the food acceptable for consumers [33]. Replacing wheat flour with several types of flour was shown in the previous section (Table 1). The evaluation of sensory characteristics and the changes of physicochemical content are properties that have a critical influence on food quality, processing and the acceptance of fortified biscuits.

### 5.1 Physicochemical Analysis

**Proximate analysis**

One of the major concerns for biscuit manufacturers is to determine how to improve the formulation of biscuits with suitable ingredients, and to increase the nutritional and functional properties of the biscuit to satisfy consumer demands. Proximate analysis can estimate the characteristics of the food products that affect consumers' food choices [86]. This analysis provides basic information related to the water, protein, fiber, ash, fat and carbohydrate contents of biscuits. Protein is an essential nutrient responsible for multiple functions in biscuits, such as texture and *in vitro* digestion [40]. The protein contents of different ingredients have been observed even within the same varieties of purple rice [55]. Dietary fiber is mostly found in cereal grains and influences biscuit quality. The inclusion of dietary fiber into the biscuit mix affects biscuit dough shrinkage and thickness, as well as reducing the force needed to snap fortified biscuits during texture analysis [41]. In baking, water provides the medium for the physicochemical reactions that convert raw materials into the finished baked foods [87]. Increasing the water level in biscuit doughs will raise the hardness of finished baked products and this tends to be good for the final product [87]. Therefore, proximate compositions have an influence on the overall quality of the biscuits. The information from proximate analysis is essential for labeling purposes [10], since the purpose of the fortification of food products is to improve the nutritional value of the product and change the characteristics of the final product [10]. It is important to emphasize that despite the declaration of nutritional compositions, the levels of these contents are useful information for both consumers and health professionals.

**Biscuit quality and color measurement**

The most important characteristic of the quality of biscuits produced from any ingredients is its appearance, including shape, size and color, as consumers can easily be influenced by the appearance of food products. An understanding of the combination of the ingredients, together with baking process, has an important effect on the quality and color of the final product [19]. Andresen et al. [88] suggested that the main drivers determining consumer preferences of biscuits are closely related to the major ingredients, the spreadability of the biscuits and appearance (i.e. width and thickness) because these aspects can make biscuits look delicious. Rice flour is used to make biscuits more spreadable; however, rice flour is known to have significantly lower protein contents and viscosity in comparison to refined wheat flour [89].

The color and appearance are the first parameters that a consumer uses in their decision to purchase a product [50]. A colorimeter calibrated to measure the CIE L*a*b* color scale is an important tool during manufacturing to maintain a consistent color during commercial production. The development of biscuits needs to maintain or improve the appearance of biscuits in order to give the consistency consumers expects. Since, the measurement of color, which has also been used as quality parameters in food industries, is an important consideration when foods are fortified by various colored ingredients [90].

**Texture analysis**

The texture, appearance and flavor of food products are the important key factors for sampling, buying and repurchasing by consumers. Texture analysis is also important to predict the acceptability of the finished product, since it can predict the force needed to bite through a biscuit [10]. Multiple component biscuits are characterized by different mechanical properties within a single bite. Although, the product has an acceptable flavor and color, an undesirable texture in a food product can easily be a factor that influences whether a customer will continue to purchase the product or not. Therefore, the development of biscuits must be carefully designed in order to meet the required physicochemical properties among various environmental conditions, such as processing and storage. Changing the formulation of any products may alter their texture and consistency. To improve consumer acceptance of new products more research needs to be undertaken to improve the nutritional contents and the appearance of the products. In biscuits, hardness is influenced by particle size distribution, and the fat and protein contents. Consumers tend to like soft biscuits [91]; however, consumer perceptions vary in different countries and between ethnic groups [92]. The optimization of the grinding process needs to be controlled as well, the ingredients can change the texture of the biscuits [93]. Therefore, new products need to be assessed using a wide range of properties, such as hardness, springiness, fracturability, cohesiveness, etc. [10] Texture analysis instruments are a way of giving numbers to these physical properties [93]. Consequently, analytical techniques are needed to test foods to ensure that they have the appropriate physicochemical properties that meet consumer demands [10].

### 5.2 Sensory Evaluation

Following the development of a new product, it is necessary to measure both physicochemical characteristics along with sensory evaluation using the ethnic groups the product is intended for [92]. Determining how new food products affect consumers' acceptance is one of the main goals that food scientists need to develop healthier recipes. Whereas some attributes of a food, such as nutritional quality, can be measured by chemical analysis, food acceptability is not easy to measure since it is very subjective. One of the biggest challenges in creating a new food product is predicting how it will be accepted by consumers. Sensory evaluation is a scientific method that uses human senses, such as vision, taste, smell and touch, to evaluate the characteristics of foods [94].

There are three different methods that use different kinds of information and methods; discrimination (paired comparison, duo–trio, triangle, etc.), descriptive (quantitative descriptive analysis, etc.) and affective (acceptance, preference, 9-point hedonic, labeled magnitude (LAM) scale). A hedonic scale is used as a simple and effective method to apply in many areas, such as, the inspection of raw materials, correlation between the target products and the prototypes (instrumental analysis), determination of food choices, product development and improvement, quality control, cost reduction and storage studies, together with critical information about individuals' likes and dislikes of food products [95]. The 9-point hedonic scale is most often used to test foods, beverages and consumer products [94]. This category-type scale uses a series of nine verbal categories ranging from "1 = dislike extremely" to "9 = like extremely." A neutral midpoint (5 = neither like nor dislike) is included. Consumers or panelists rate the product on the scale based on their response. The development of new food products, in terms of marketing, the guidelines require a sensory score above 7 to proceed to production [95].

 

Therefore, the hedonic scale is a suitable method to predict the acceptability of a new innovative product or to improve a product so that it will be accepted by consumers. This test can be conducted using untrained consumer panels; however, descriptive analysis techniques require trained panellists [95]. Typically, a hedonic test needs between 75–150 consumers and each test needs to be carried out using standardized equipment and protocols [94].

Many researchers have compared consumer taste tests of new bakery products using instrumental analysis [44,50,51,93,96]. Williams et al. [92] showed that there was a correlation between the analytical results obtained from human-based sensory analysis (such as crunchiness, softness, or hardness) and results obtained using mechanical instrumentation. Unfortunately, many people do not have sufficient experience to evaluate taste sensations, such as sweetness, saltiness or sourness. In addition, different ethnic groups perceive the taste of foods in quite different ways. Comparisons of eating, food choices and the nutrition of different cultures have received more attention in recent studies [92]. Recently, there were several studies that have reported a correlation in food choices and taste preferences among individuals, groups or cultures. Reed et al. [97] reported that different ethnic groups showed significantly different responses in taste intensity due to genetic variations. In addition, human behavior toward food consumption choices can be affected in various ways due to the complex nature of human motives and emotions. Prescott et al. [98] studied the influence of consumers' eating habits in many European and Asian countries and found that health, weight control, convenience, mood, natural content, sensory appeal, price, and familiarity are important factors influencing consumers' food choices. Studies on human preferences across various cultures provide significant data and increase our understanding of ethnic influences on individual preferences [99]. When attempting to modify the nutritional value of biscuits, different ethnicities need to be involved since these individuals may have distinct preferences.

## 6 Lipid Oxidation in Biscuits

One of most important non-microbial degradations that can occur in biscuits is oxidation, which results in a change of color, aroma and flavor and loss in nutritional value [100]. Lipids, which are one of the main components of biscuits, can be oxidized by non-enzymatic and enzymatic reactions related to many mechanisms such as photooxidation, enzymatic oxidation and autoxidation. Autoxidation is the most important mechanism of lipid oxidation during storage of biscuits induced by a continuous free-radical chain reaction. It also involves with three sequences: initial oxidation, propagation and termination [101]. Lipid oxidation leads to the formation of a fat hydroperoxide (primary oxidation products at propagation stage), which are tasteless, odorless and very unstable and decompose to form secondary oxidation products such as aldehydes, ketones and carboniles that adversely affect to food flavor quality [102]. Lipid oxidation is known to cause rancidity in many types of foods, including low moisture food (water activity lower than 0.5) [103] and with small amounts of lipids (less than 1%) [104]. The effects of lipid oxidation from triacylglycerols and phospholipids in butter are changes in functional and sensory characteristics and decreased shelf life [48,104]. Lipids containing high amount of polyunsaturated fatty acids are also highly susceptible to the oxidation [101]. Free fatty acid (FFA) content is another quality indicator and acted as a pro-oxidant. The FFA is a hydrolytic rancidity product, which is an important value to determine the quality parameter of fat-containing foods. Since, FFA can be generated by microbial activity that leads to strong flavors and odors at comparatively very low levels. The determination of FFA is important factor for rancidity shelf life testing of foods. Products also can be assessed by assessing the formation of compounds, such as peroxide values (PV) and TBA reactive substances (TBARS), which are most commonly evaluated in food products [48]. PV is a useful indicator of the extent of the primary oxidation of rancidification (the concentration of hydroperoxides decomposes during storage) from oils and fats, which depends on temperature, time, light content of unsaturated fatty acids and processing. Aldehydes are key compounds of the secondary lipid oxidation products, which also affect the modifications of nutritional properties. Although PV is the most used parameter for estimating the overall oxidation status for lipids, it is not possible to use only this value to judge the rancidity of oils in foods [100].

 

## 7 Natural Antioxidants in Spices Can Inhibit Oxidation

In recent years, interest in the use of natural antioxidants has risen in improving the oxidative stability of foods. The effectiveness of antioxidant compounds results from their free radical-scavenging activity, the presence of regenerating and/or synergistic antioxidants also have important positive effects [104]. Numerous studies have indicated that antioxidants are useful compounds to reduce lipid oxidation [105]. Many types of plants that naturally contain antioxidants (polyphenols), such as grape seeds, are used as a source of antioxidant incorporated in food products [106], as well as ginger [107], rosemary [108], cinnamon [109], nutmeg [110-112], ginger [113] and galangal [114]. The antioxidant activity of spices has been studied as potential and additional sources of natural antioxidants. Spices contain large amounts of bioactive compounds consisting of phenolic compounds, flavonoids, tannins and vitamins that show different antioxidant activities depending on the type of spice [115]. Buaniaw et al. [114] studied the effect of an ethanol galangal extract on minced sea bass and observed it inhibited lipid oxidation. Moreover, curry spice, rosemary and thyme when incorporated in the biscuit mix had good sensorial acceptability with a potential to improve oxidative stability of fat in the biscuits [101,131]. Preliminary studies of Klunklin and Savage [45, 46] were also stated that antioxidant compounds from spice mixtures might have a potential to maintain the quality of wheat-purple rice biscuit containing defatted mussel powder during storage.

## 8 Conclusions

Biscuits are popular snack foods made from flour, sugar and fat. Many researchers have tried to develop new nutritious products by incorporating new bioactive compounds and different proteins into biscuits. Substitution of various types of flour for wheat flour was becoming popular because of the nutritional advantages it provided. Purple rice, widely grown in Northern Thailand, was a good choice to replace wheat flour because it contained high fiber contents and a range of antioxidants. In terms of nutritional values, purple rice flour has several nutritional advantages over refined wheat flour, such as higher protein, vitamin and mineral contents. Nevertheless, the consumer acceptability of healthier purple rice flour biscuit should also be considered; on the one hand, since the partial replacement of purple rice flour for wheat flour changes both the chemical and physical characteristics (e.g. hardness). On the other hand, lipids were a major cause for both desirable and undesirable flavors that occurred in biscuits. Several studies have indicated that natural antioxidants were useful compounds to include in biscuits to reduce lipid oxidation during storage. However, at the present, there were very few publications that reported the use of purple rice flour to make biscuits; therefore, further study was essential to improve the sensory attributes of purple rice flour supplemented biscuits. There is considerable potential to use purple rice flour in other related food products.

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