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MiniReview

Applications of composite flour in development of food products

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Abstract

The development of food products using composite flour has increased and is attracting much attention from researchers, especially in the production of bakery products and pastries. This article focuses on the use of composite flour to produce food products, namely bread, biscuits, and pasta, with looks at on its impact, following some improvements made, on the sensory quality, rheology characteristics, and nutritional values as well as its overall acceptance. The blending of wheat flour with various sources of tubers, legumes, cereals and fruit flour in different percentages to produce variety of food products are also reported in this review. It was found that composite flour used to produce food products is still able to maintain similar characteristics to products made from full-wheat flour. The positive effects of the use of composite flour can be seen in the final product related to the functional and physicochemical properties and health benefits of raw blended flour along with percentage blending. Overall, composite flour is a good new approach to utilizing uncommon food products as the application of composite flour produced products with different characteristics and quality, depending on the types and percentage of wheat flour used in the formulation.

Introduction

Milligan *et al*. (1981) defined composite flour as a mixture of flours, starches and other ingredients intended to replace wheat flour totally or partially in bakery and pastry products. Shittu *et al.* (2007) also agreed with that as the composite flours used were either binary or ternary mixtures of flours from some other crops with or without wheat flour. The use of composite flours had a few advantages for developing countries such as Malaysia in terms of: i) the saving of hard currency; ii) promotion of high-yielding, native plant species; iii) a better supply of protein for human nutrition; and iv) better overall use of domestic agriculture production (Berghofer, 2000; Bugusu *et al.*, 2001). Composite flour is considered advantageous in developing countries as it reduces the importation of wheat flour and encourages the use of locally grown crops as flour (Hugo *et al.*, 2000; Hasmadi *et al*., 2014). Local raw materials substitution for wheat flour is increasing due to the growing market for confectioneries (Noor Aziah and Komathi, 2009). Thus, several developing countries have encouraged the initiation of programmes to evaluate the feasibility of alternative locally available flours as a substitute for wheat flour (Abdelghafor *et al*., 2011).

Moreover, the concept of composite technology initiated by the Food and Health Organization (FAO) in 1964 was targeted reducing the cost of support for temperate countries by encouraging the use of indigenous crops such as cassava, yam, maize and others in partial substitution of wheat flour (Satin, 1988). The FAO reported that the application of composite flour in various food products would be economically advantageous if the imports of wheat could be reduced or even eliminated, and that demand for bread and pastry products could be met by the use of domestically grown products instead of wheat (Jisha *et al*., 2008). The bakery products produced using composite flour were of good quality, with some characteristics similar to wheat-flour bread, though the texture and the properties of the composite flour bakery products were different from those made from wheat flour, with an increased nutritional value and the appearance. Apart from being a good source of calories and other nutrients, wheat is considered nutritionally poor, as cereal proteins are deficient in essential amino acids such as lysine and threonine (Dhingra and Jood, 2001). Therefore, supplementation of wheat flour with inexpensive staples, such as cereals and pulses, helps improve the nutritional quality of wheat products (Sharma *et al*., 1999). For example, the protein quality of both the cassava-soya and the cassava-groundnut breads is higher than that of common wheat bread (Nilufer *et al*., 2008).

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In Malaysia, the bakery industry has grown tremendously over recent years (Noor Aziah and Komathi, 2009). According to Sudha *et al.* (2007), bakery products are varied by the addition of value-added ingredients. Thus, the increasing number of applications of composite flour in numerous bakery and pastry products has spurred a growing number of studies on the effects of different types of materials used to produce flour on their physicochemical and functional properties. Mepba *et al.* (2007) reported that the experience gained in the use of composite flours has clearly demonstrated that, for reasons of both product technology and consumer acceptance, wheat is an essential component in many composite flours. They also reported that the percentage of wheat flour required to achieve a certain effect in composite flours depends heavily on the quality and quantity of wheat gluten and the nature of the product involved. Therefore, when bakery and pastry products are produced using composite flour, their quality should be as similar as possible to those of products made from wheat flour. In this review paper, the application of composite flour its impact, following some improvements made, on the sensory qualities, rheology characteristics, and nutritional values of different types of food products are reported. The review starts with bread, followed by biscuits, and pasta.

Bread

Bread consumption has increased continuously in many developing countries due to changing eating habits, a steadily growing population and because a large proportion of the overall increased incomes can now be spent on foods (Seibel, 2011). However, the wheat flour needed for making bread had to be imported, since the climatic conditions and soil did not permit wheat to be grown locally (Seibel, 2011). Thus, research interest in composite flours has been on the rise in the recent past, driven by the desire to find non-wheat bread-making alternatives in order to reduce non-wheat-producing countries' dependence on imported wheat (Mepba *et al.*, 2007). Much effort has been made to promote the use of composite flours, in which a portion of wheat flour is replaced by locally grown crops, in bread, thereby decreasing the cost associated with with imported wheat (Olaoye *et al.*, 2006), which in turn decreases the demand for imported wheat while producing protein-enriched bread (Giami *et al*., 2004). Flours from corn, barley, cassava and chickpea are among the most predominant studied for the production of composite flour breads (Defloor *et al*., 1993; Ali *et al*., 2000).

Legume proteins can be successfully used in baked products to obtain a protein-enriched product with improved amino acid balance (Bojňanská *et al*., 2012; Mohammed *et al*., 2012). One of the most important properties of legume proteins is their high content of lysine, an essential amino acid, and their deficiency in sulphur-containing amino acids, which makes them a great complement to other well-known cereal proteins (e.g., wheat) which are deficient in lysine, but have good sulphur amino acid content (Eggum and Beame, 1983). The potential use of legumes as protein-enriching agents of baked products, mainly in the form of protein flours, has been reported by several authors. Among the legume protein products tested are various soy bean protein preparations (Ribotta *et al*., 2005), chickpea flour (Gômez *et al*., 2008), germinated chickpea flour (Fernandez and Berry, 1989), germinated pea flour (Sadowska *et al*., 2003) and lupin flour (Doxastakis *et al*., 2002; Pollard *et al.*, 2002).

As an important component crop, soy is the legume richest in nutrients, is known to be a good source of the trace elements copper, zinc and manganese, and can be said to contain all the nutrients needed in food (Ampofo, 2009). Its use in the production of bread as a composite flour has been reported (Dhingra and Jood, 2002; Basman *et al.*, 2003). Supplementation of wheat flour with not more than 30% soy bean flour would greatly improve the quantity of nutritional protein in bread. The increase in the protein content of the bread could be due to the significant quantity of nutritional protein in the soy bean seeds (Basman et al., 2003). The bread-making quality of wheat is mainly related to the protein and gluten content of the grain and flour. However, the protein and gluten composition also has a great impact on the dough properties, such as water absorption and mixing stability, CO_2-retention capability, and the bread volume (Waagepetersen *et al*., 2001). Therefore, the addition of germinated soy bean flour to wheat flour improves the overall bread quality and results in a higher specific volume (Dominguez *et al*., 2008). Soy protein products are also known for their improved crust colour, crumb body, resilience and toasting characteristics in bread (Nilufer *et al*., 2008) while also extending shelf-life (Vittadini and Vodovotz, 2003).

However, there is a lower acceptance of soy-wheat bread due to the beany flavours imparted by soy flour, especially at levels of above 15% soy flour substitution for wheat (Hettiarachchy and Kalapathy, 1997). The deleterious effects of legume flours on bread are minimized by the use of surfactants and oxidizing improvers, which improve the dough strength of soy-wheat bread but do not minimize the beany flavours (Maforimbo *et al.*, 2006). The use of physically modified legume flour made from the optimal thermal treatment of the beans to destroy the lipoxygenase and retain the functional and nutritional properties may be another way to get around the problem of product acceptance (Maforimbo *et al.*, 2006). L-threo ascorbic acid (vitamin C) is widely used as a bread improver in wheat breads, which is achieved by the oxidation of L-ascorbic acid (L-AA) to dehydro-ascorbic acid (DAA) and this becomes the oxidizing agent (Grosch and Wieser, 1999). Because of the likelihood of high levels of free radicals from the oxidation of free fatty acids in soy flour, L-AA is also capable of participating in the scavenging of these free radicals. From a theoretical consideration, such a dough system would consume more L-AA than the wheat dough (Maforimbo *et al.*, 2006). The fact that L-ascorbic acid is easily available, a permitted food ingredient and does not leave toxic compounds in the final product makes it superior to other oxidizing agents. L-ascorbic acid used by Maforimbo *et al.* (2006) was higher (up to 2300 ppm) than the recommended concentration used to strengthen bread, 20-30 ppm (Grosch and Wieser, 1999). Thus, the use of L-ascorbic acid and physically modified soy flours was considered effective in strengthening soy-wheat composite dough and this could be a positive step towards the promotion of higher levels of soy flour in wheat bread (Maforimbo *et al*., 2006).

In addition, breads made from both barley and defatted soy flours, up to 15% level, are also considered as most acceptable, organoleptically and nutritionally as they contain appreciable amounts of protein, total lysine, dietary fibre, β-glucan and minerals (Dhingra and Jood, 2001). The soluble β-glucans are present primarily in the endospermic cell walls of barley grain (Jood and Kalra, 2001) which has been reported to be useful in regulating cholesterol levels and blood glucose levels (Knuckles *et al*., 1997). Knuckles *et al.* (1997) also found that total, soluble and insoluble β-glucan contents increase several times in breads containing α, β-glucan-rich barley fraction at different levels, as compared with control bread. Skendi *et al.* (2010) observed that the inclusion of β-glucan in wheat flour is accompanied by a decrease in loaf specific volume, the extent of decrease depending on β-glucan level. Dhingra and Jood (2001) found that, at 15% level of supplementation with barley flour, there was an increase of 10, 13 and 7% in total, soluble and insoluble dietary fibre content of bread as compared to control.

In addition, legumes such as lentil, pea, and chickpea are an important source of proteins, carbohydrates, vitamins and minerals and are widely consumed in some traditional diets (Dodok *et al*., 1993). Since protein has a major role determining the quality of bread, supplementation of wheat dough with chickpea or other grain legume flours and proteins certainly affects the rheological properties of the fortified wheat flour dough and its subsequent finished products (Eliasson, 1990). These effects can be measured by using physical dough-testing devices to evaluate the bread-making potential and performance characteristics of the fortified flour (Mohammed *et al*., 2012). The higher the addition of lentil and chickpea the worse the qualitative parameters of baked bread loaves, mainly with regard to their volume and volume efficiency (Bojňanská *et al.*, 2012). The reason for the decreased volume is mainly the decrease in the amount of gluten caused by the addition of materials from which it is not possible to isolate gluten. By lowering the amount of gluten, the ability to keep ferment gas during the rising of dough is also lowered and consequently it influences the lower volume and lower porosity of pastries (Bojňanská *et al*., 2012). The same tendency has been observed in loaves' cambering, which is the ratio between the height and the width, and its higher value points to a loaf with a more arching, more desirable form (Bojňanská *et al*., 2012). Gluten proteins play a key role in guaranteeing the bakery quality of wheat, and influence water absorption, cohesion, viscosity, extensibility, elasticity, resistance to deformation, tolerance to kneading, ability to gas retention and dough-strengthening properties (Lazaridou *et al.*, 2007; Wieser, 2007). Most non-wheat flours are devoid of gluten and its addition impairs the bread-making quality of wheat flour.

Therefore, vital wheat gluten, a by-product of the wheat starch extraction process, has been shown to improve the bread-making properties of weak flours (Stenvert *et al.*, 1981; Wiepert and Lindhauer, 1999), improve loaf volume, crumb grain, texture, softness and shelf life. Stenvert *et al.* (1981) showed that adding up 35 ppm sodium metabisulphite, a reducing agent, significantly improved the baking performance of poor-quality vital gluten. Sodium metabisulphite acts by 'softening' dry vital gluten so that it attains optimal development and thus gas-retaining capacity at the same time as the endogenous gluten. This principle is employed in the activated dough development process in which balanced blends of reducing and oxidizing agents are used to bring about dough maturation (De Ruiter, 1978).

For flours substituted with modified starches, Miyazaki *et al*. (2006) recommended that the starch content should not exceed 20% and that the amount of vital gluten added should be 8% of the weight of starch substitution, a weight almost equal to the percentage of insoluble wheat protein, glutenin and gliadin combined in wheat flour. There are also other technologies that improve composite bread baking, including intensive dough mixing, sponge and dough system, chemical/activated-dough development, short proof times and use of dough conditioners and bread improvers (De Ruiter, 1978). Luwangula *et al.* (2004) identified water absorption as a critical parameter in composite bread baking which could potentially improve bread quality when optimized. However, Muranga *et al.* (2010) identified that the interactive effect between farinograph water absorption and vital gluten was negative, showing that gluten required reduced water levels to facilitate its setting during baking.

Likewise, Bojňanská *et al.* (2012) reported that during the baking experiment crumb acidity increased with the addition of lentil and chickpea, thus the bread became tastier and richer. The highest increase of acidity was found in bread loaves with the addition of lentil which is most probably related to the high input of minerals coming from this raw material (Bojňanská *et al.*, 2012). Heat treatment applied to legumes improves their texture, palatability and nutritive value by the gelatinization of starch, denaturation of proteins, increased nutrient availability and inactivation of heat labile toxic compounds and other enzyme inhibitors (Bojňanská *et al.*, 2012). Furthermore, some studies have shown additional benefits of pulse flour use, such as an increase in mineral bioavailability and a lowering of glycaemic response in healthy consumers when pulses, such as chickpea flour, are added to the diet (Goñi and Valentín-Gamazo, 2003).

Bread can also be prepared with the inclusion of malted rice flour at 35% and wheat flour at 65% to produce bread with better consumer acceptability and nutritional value than wheat bread. The principal functional benefits of the addition of malted rice flour include increased gas production in the dough and an improved crust colour formation, a better crumb moisture retention and enhanced flavour development (Veluppillai *et al.*, 2010). It has been reported that the inclusion of malted rice flour in bread can significantly reduce the glycaemic index of bread and may be a better choice for the management of diabetics. Veluppillai *et al.* (2010) also reported that the use of germinated rice flour has advantages over the use of raw rice flour for bread making, and that increasing germination time might improve the physical and nutritional quality of bread. The use of rice flour in bread making is still limited due to the fact that rice proteins are unable to retain gas produced during the fermentation process, resulting in a product that has a low specific volume, which does not resemble wheat bread (Gujral and Rosell, 2004a). Gujral and Rosell (2004a) also reported that rice has few prolamins (2.5-3.5%) and as a result a viscoelastic dough is not formed when rice flour is kneaded with water. However, the incorporation of hydroxypropyl methylcellulose (HPMC) at levels of 4% in rice flour has made it possible to produce bread from rice flour (Haque and Morris, 1994) with a specific volume comparable to that of wheat bread. A proportion of wheat flour was substituted with rice flour at the 150 g/kg for bread making, the overall acceptability of the product was the best replacement (Noomhorm and Bandola, 1994).

On the other hand, maize flour contains high levels of many important vitamins and minerals, including potassium, phosphorus, zinc, calcium, iron, thiamine, niacin, vitamin B6, and folate (Watson, 1997) and maize flour could be composited with wheat flour. The incorporation of maize flour at a level of up to 40% and defatted maize germ flour at a level of up to 15% produces bread without any negative effects in quality attributes and reasonable acceptance, offering a promising, nutritious and healthy alternative to consumers (Păucean and Man, 2013). While a composite blend of rice flour with corn and cassava starches obtains a gluten-free bread with a well-structured crumb and pleasant flavour and appearance (Lopez *et al.*, 2004). Generally, in the performance of gluten-free bread, a variety of hydrocolloids or gums have been used for creating a polymer network with similar functionality to that of the wheat gluten proteins. In fact, gluten-free breads have been successfully developed using several combinations of cellulose derivatives (Gujral and Rosell, 2004a; Schober *et al.*, 2007). With the same purpose, cross-linking enzymes (glucose oxidase and transglutaminase) have been used as processing aids for improving rice-based gluten-free bread quality (Gujral and Rosell, 2004a,b; Moore *et al.*, 2006). Lately, different proteins have been proposed as an alternative for both playing the polymer role and increasing the nutritional value of gluten-free products (Marco and Rosell, 2008a, b).

Besides legumes and cereal, cocoyam, cassava, taro and other tuber crops have been found to be alternative sources of major raw materials for bread making (Giami *et al.*, 2004). Generally, increasing the substitution amount of wheat flour with other flours progressively reduces the quality of bread. This has been attributed to reduced flour strength and gas retention capacity due to a reduction in gluten content, thereby reducing bread volume and the sensory appeal of most baked composite bread (Khalil *et al*., 2000). Partial substitution of wheat flour by cassava flour increased the weakening of the dough. This might be due to the lower water absorption of composite flours (Khalil *et al.*, 2000). Thus, partial substitution of wheat flour by cassava flour at levels of 20% and 30% and the addition of 1% malt resulted in good-quality bread similar to that obtained from wheat flour at an 82% extraction ratio (Khalil *et al*., 2000). Therefore, bread baked with up to 20% substitution of cassava flour had no adverse sensory or organoleptic effect on bread (Khalil *et al.*, 2000; Giami *et al.*, 2004; Eddy *et al.*, 2007). Owuamanam (2007) reported that it is possible to produce quality bread up with to 30% substitution of wheat flour when cassava roots were pretreated with citric acid solution before milling into flour. Also, steeping in citric acid solution for 24 hours gave the desired modification of cassava flour for a better bread quality (Owuamanam, 2007).

See *et al.* (2007) reported the addition of 5% pumpkin flour resulted in bread with high loaf volume and good overall acceptability. Mansour *et al.* (1999) reported that the addition of pumpkin and canola proteins to wheat flour resulted in an increase in water absorption. According to Wang *et al.* (2010), higher total fibre in the non-wheat flour interacts relatively well with a large amount of water through the hydroxyl group existing in the fibre structure. The 5% pumpkin flour bread had the highest loaf volume and specific volume compared to the other samples (See *et al*., 2007). The moisture content of the breads was a major factor affecting loaf volume. Increasing water level in the formulation by 10 and 20% increased the loaf volumes in bread (Gallagher *et al*., 2003). However, the lower specific loaf volume value obtained for the sole lesser yam bread samples may be attributed to their lack of the protein gluten that is responsible for the enhanced dough rise in leavened wheat bread (Ukpabi, 2010).

Other than cereals, tubers and legumes, fruit flour has also been reported used in development of composite bread, for example mango seed kernel flour (Menon *et al.*, 2014). A composite flour bread using the ratio 85:5:5:5 respectively, refined wheat flour, sprouted mung bean flour, soy flour and mango kernel flour was the best formulation with similar organoleptic and physical properties as refined wheat flour breads. Thus, Menon *et al.* (2014) identify the viability of using agricultural by-products such as mango seed kernel in the development and enrichment of leavened bread. Another study reported by Akubor and Obiegbuna (2014) identified the toasting methods of African bread fruit seed flour increased the protein, ash and crude fibre contents, while fermentation increased the protein content and boiling decreased the quality of African bread fruit seed flour for bread making. Breads containing toasted African bread fruit seed flour (30%) and refined wheat flour (70%) had higher weight, height, length and volume than other breads. Breads containing fermented African bread fruit seed flour had the highest proofing ability and specific loaf volume. Thus, Akubor and Obiegbuna (2014) suggested that toasted African bread fruit seed flour could be used as a wheat flour supplement in bread making.

Colour appeared to be a very important criterion for the initial acceptability of the baked product by the consumer. Moreover, as the development of colour occurs classically during the later stages of baking, it can be used to judge completion of the baking process (Zanoni *et al*., 1995). Surface colour depends both on the physicochemical characteristics of the raw dough (i.e. water content, pH, reducing sugars and amino acid content) and on the operating conditions applied during baking (i.e. temperature, air speed, relative humidity, modes of heat transfer) (Zanoni *et al.*, 1995). See *et al.* (2012) reported the colour of the bread was significantly affected ($p < 0.05$) by the addition of pumpkin flour. The colour of the crust showed a significant decrease ($p < 0.05$) in the L value of pumpkin flour supplemented bread. This is also reported for lesser yam-wheat bread by Ukpabi (2010). This may be because loaves containing additional glucose have a darker crust. This condition is attributed to Maillard browning caused by the reaction between wheat proteins and the added sugar (Fayle and Gerrard, 2002) and caramelization, which are influenced by the distribution of water and the reaction of added sugars and amino acids (Kent and Evers, 1994) due to a higher lysine content (Mohammed *et al.*, 2012). In the Maillard reaction, reducing carbohydrates react with free amino acid side chains of mainly lysine protein and lead to amino acid–sugar reaction products (polymerized protein and brown pigments). This reaction may compromise the nutritional value of foods through the blocking and destruction of essential amino nutrients (Mohammed *et al*., 2012). According to Hodge (1967), the Maillard reaction is related to temperature, time and the presence of water (moisture). Table 1 shows the acceptable formulation of bread made using composite flour in terms of sensory quality, with the strong and weak characteristics in the rheological properties as well as the nutritional values.

Biscuits/Cookies

Among ready-to-eat snacks, biscuits/cookies

Table 1. Acceptable formulation for development of composite bread in terms of sensory quality with the strengths and weaknesses characteristics in rheological properties and nutritional values.

Composite flour (s)	Reported by	Acceptable formulation, (%)	Strengths characteristic	Weaknesses characteristic
Soy bean wheat	Ndife *et al*., 2011	10:90	Higher protein, fat and crude fibre content.	Low scores in organoleptic attributes.
Chickpea wheat	Mohammed *et al*., 2012	10 to >20	An increase water absorption of the dough, and an improved volume, internal structure and texture of the breads.	Strong brown colour, a hard crust on bread.
Lupin-wheat	Ahmed *et al*., 2012	15:85	Increased maximum deformation of dough and elastic recovery.	Flow ability very low.
Cowpea-wheat	Masood *et al*., 2011	10:90	Increased protein, fibre, fat, ash contents, water. Absorption, dough development time, and dough stability.	Gluten contents, sedimentation and pelshenke value and peak height of the blend decreased. The bread volume decreased.
Cassava-wheat	Eddy *et al*., 2007	10 to 20	-	Low carbohydrate, protein and crude fibre.
Cocoyam-wheat	Mongi *et al*., 2011	10:90	Carbohydrate, crude fibre, and ash contents increased. Loaf weight bread increased.	Moisture and protein contents decreased. Loaf volume and specific loaf volume decreased.
Yam-wheat	Mojioni *et al*., 2013	20:80	Retained bread volume and sensory characteristic and decreased glycaemic index of bread.	-
Taro-wheat	Ammar *et al*., 2009	10:90	Ash, total carbohydrates and fibre contents increased. Increased in water absorption and dough weakening and the dough extensibility.	Decreasing in the crude protein and ether extract. Decreased mixing time and dough stability, dough energy, and the resistance to extension.
Sweet potato-wheat	Oluwalana *et al*., 2012	15:85	No significant difference in the crust colour, crumb holes, stability, elasticity, firmness, shape regularity and appearance of bread with control	-
Maize-wheat	Begum *et al*., 2013	10:90	Volume and specific volume breads highly positively correlated with taste, texture and overall acceptability.	Adversely affected the baking properties and dough expansion. Hardness and springiness deteriorated during storage.
Buckwheat-wheat	Wronkowska *et al*., 2008	30:70	Enrichment in nutrients, especially in proteins and elements as well as resistant starch.	-
Sorghum-wheat	Abdelghafor *et al*., 2011	30:70	Increased hardness, gumminess and chewiness.	Decreased cohesiveness, springiness and resilience.
Pumpkin-wheat	Pasha *et al*., 2013	5:95	Increased in ash content and water absorption.	Decreased in dough development.
Breadfruit-wheat	Ayodele and Aladesanmi, 2013	20:80	Protein and fat content of the bread produced increased.	Has flavour and lack in textural properties.
Jackfruit rind-wheat	Feili *et al*., 2013	5:95	-	Significant influence on bread volume and texture attributes, increase in hardness and darkness of bread.
Banana-wheat	Zuwariah and Noor Aziah, 2009	20:80	Highest phenolic content.	Increased the compactness and hardness of bread.

possess several attractive features, including a wider consumption base, relatively long shelf life, greater convenience and good eating quality (Hooda and Jood, 2005). The growing interest in these types of bakery products is due to their better nutritional properties and the possibility of their use in feeding programmes and catastrophic situations such as starvation or earthquakes (Pratima and Yadava, 2000). In many countries, cookies are prepared with fortified or composite flour to increase their nutritive value (Gonzalez-Galan *et al*., 1991) – for example, the high-protein cookies made using composite flours that include blends of soy bean (Shrestha and Noomhorm, 2002) with field pea and defatted peanut replacing the wheat flour by up to 30 g/100 g (McWatters, 1978) and with chickpea and lupin by up to 20 g/100 g (Faheid and Hegazi, 1991). Legumes are higher in nutrients, especially in protein (18–24%), than cereal grain (Noor Aziah *et al.*, 2012). Cowpea and peanut flour have been reported to successfully replace up to 20% wheat flour in cookies (McWatters, 1978).There are also reports of cookies with up to 30 g/100 g of navy bean and sesame seed flours (Hoojjat and Zabik, 1984), pigeon pea flour (Eneche, 1999), as well as with pulse flours and fibres (Piteira *et al.*, 2006).

Noor Aziah *et al*. (2012) reported the incorporation of chickpea flour and mung bean flour into wheat flour does not change the functional properties but increases the protein, resistant starch content and acceptability of cookies. However, aftertaste was found to be pronounced in the mung bean and chickpea cookies (Noor Aziah *et al.*, 2012). McWatters (1978) suggested that the beany flavour in legume flour could be reduced by exposing the material to moist heat. In addition, more strength was needed to break cookies incorporated with legume flour (Noor Aziah *et al*., 2012) which might have resulted from the incorporation of protein-rich flour which needs more water to obtain good cookie dough, and the cookies prepared from high-absorption dough tend to be extremely hard (Hoojjat and Zabik, 1984). Chickpea cookies were observed to have a higher crispiness value compared to mung bean cookies (Noor Aziah *et al*., 2012) indicating that this might have resulted from the water-binding effort in mung bean flour which increased with the heat denaturation of protein content (Del Rosario and Flores, 1981). Noor Aziah *et al.* (2012) reported that chickpea cookies have the highest diameter even though the protein content is high. This may cause the viscosity of chickpea dough to reduce and increase the spread rate. Dough with lower viscosity causes cookies to spread at a faster rate (Hoseney and Roger, 1994).

Saeed *et al.* (2012) reported that a proportion of 90:10 of plain wheat flour and sweet potato flour produced good results without any adverse effect on the physical and sensory characteristics of cookies. It has been established that cookies' spread is strongly correlated to the water absorption capacities of the flour (Vieira *et al*., 2007). Since the water absorption capacity of sweet potato flour (2.375 ml/g) is higher than that of wheat flour (1 ml/g), rapid partitioning of free water to hydrophilic sites of sweet potato flour is presumed to be higher than that of wheat flour (Saeed *et al*., 2012). It was also noted that sweet potato flour improved the flavour and texture of cookies and can significantly improve the dietary fibre and mineral contents of the product (Saeed *et al*., 2012).

The biscuits formed with the addition of 20 and 30% buckwheat flour had an overall acceptability score of 6.71 and 6.20, respectively, suggesting acceptability to the consumers (Baljeet *et al.*, 2010). As the concentration of buckwheat flour was increased, the spread ratio of the biscuits decreased (Baljeet *et al.*, 2010). However, Singh *et al.* (2003) reported the cookies' spread factor increased with the addition of corn and potato flours. The fracture strength of biscuits decreased with the incorporation of buckwheat flour (Baljeet *et al*., 2010). This also happened with the addition of both corn and potato flours to wheat flour at different levels (2, 4, 6%) (Singh *et al.*, 2003). Furthermore, the buckwheat flour is superior to the wheat flour because of its higher lysine, iron copper and magnesium content (Ikeda and Yamashita, 1994). The significant contents of rutin, catechins and other polyphenols as well as their potential antioxidant activity are also of great importance (Wanatabe, 1998). These functional components of buckwheat have health benefits such as reducing high blood pressure, lowering cholesterol, controlling blood sugar and minimizing cancer risk (Kim *et al*., 2004).

Saha *et al.* (2011) studied the possibility of using finger millet in the preparation of composite flour and biscuits and Krishnan *et al.* (2011) stated that wheat flour could be substituted by finger millet seed coat matter by up to 20% for the preparation of gluco-type biscuits. However, there was not much variation in the diameter of the biscuits although the thickness varied slightly (Krishnan *et al.*, 2011). Fenugreek flour could be incorporated up to a level of 10% in the formulation of biscuits without affecting their overall quality, physical, sensory or nutritional characteristics (Hooda and Jood, 2005). The thickness of fenugreek-supplemented biscuits increased, whereas the width and spread ratio of the biscuits decreased with the increasing level of fenugreek flour. An increase in the protein content tends to reduce the length of biscuits after baking. The quantitative and qualitative importance of the proteins is well known, though the influence of gluten on the quality of biscuit dough is difficult to define (Saha *et al*., 2011). Therefore, in their study, composite flour, made by blending finger millet and wheat flour in a 60 to 40 ratio was found to be the best in providing a better physical quality biscuit dough and biscuits in terms of its spread ratio, density and breaking strength.

Pasta

Pasta is a stable food product that is produced mainly by mixing durum wheat semolina and water (Sozer, 2009). In recent years, pasta has become recognized as a healthy food, with a low fat content, no cholesterol and a low glycaemic index (Cleary and Brennan, 2006). In pasta processing, gluten is considered to be the most significant factor related to pasta cooking quality (Dexter and Matsuo, 1978). Gluten consists of gliadin and glutenin and is responsible for elasticity and al dente chewability of pasta, which is highly appreciated by consumers (Sozer, 2009).

Since rice protein lacks the functionality of wheat gluten in making a cohesive dough structure, some starch gelatinization is required to act as a binder when rice is the only material used in pasta production (Sozer, 2009). Due to the absence of a binding agent in rice, the water absorption rate is very low. Thus, a system with a definable structure cannot be formed and there are also repulsive forces acting between the starch granules due to the absence of a binding agent (Sivaramakrishnan *et al.*, 2004). In the presence of polymers like gum and protein the attractive forces increase (Chanamai and McClements, 2001). The gum addition could help to form a kind of network structure which entraps starch granules due to galactomannans (Sozer, 2009). Both the addition of gum and protein increased the amount of polymers in the system (MacGregor and Greenwood, 1980) and resulted in increased elasticity. Lazaridou et al. (2007) indicated that improvement of viscoelastic properties of doughs by the incorporation of hydrocolloids is expected because of the enhanced viscoelastic properties of the polysaccharides in the aqueous medium. From the creep-recovery and dynamic oscillation measurements it was found that a guar gum and protein mixture can be used as a stabilizer together with 50% pre-gelatinized rice semolina. This will result in an improvement in dough properties during the processing of gluten-free pasta from rice (Sozer, 2009). In a preliminary study by Marti *et al.* (2010), rice is recommended as safe for people affected by coeliac disease and is commonly used to produce gluten-free pasta, alone or in combination with other no-gluten cereals and/or additives as composite.

Since the protein content in sweet potato is low, Limroongreungrat and Huang (2007) used protein sources such as soy flour and soy protein concentrate to enhance the nutritive quality of products. In their study, pasta fortified with 15 g/100 g defatted soy flour or 15 g/100 g soy protein concentrate had approximately five times higher protein content compared to pasta made from 100 g/100 g alkaline-treated sweet potato flour. Furthermore, these products also had cooking quality, stickiness, cohesiveness, and springiness similar to pasta made from 100 g/100 g alkaline-treated sweet potato flour. However, partial or complete substitution of durum wheat semolina with fibre material can result in negative changes to pasta quality, including increased cooking loss (Cleary and Brennan, 2006). In previous investigations, cooking loss for a good-quality pasta should be lower than 12% and a partial or complete substitution of durum wheat with another material can result in negative changes (Cleary and Brennan, 2006), as was found when using 5–30% yellow peas, lentils and chickpeas

(Zhao *et al.*, 2005) and 15% banana flour (Ovando-Martinez *et al*., 2009). Another study reported by Baljeet *et al.* (2014) stated that blends of refined wheat flour with colocasia, sweet potato and water chestnut flours respectively at a replacement level of 25 g/100 g were assessed for their suitability for noodles making. Noodles prepared from respective flour blends of sweet potato and colocasia flour with refined wheat flour showed lower cooking time, higher cooked weight, higher water uptake and higher gruel solid loss. Noodles with acceptable quality characteristics and a decreased level of gluten may prove beneficial for coeliac persons (Baljeet *et al*., 2014)

Spaghetti is pasta in the form of long strings (World English Dictionary, 2009). The fortified spaghetti firmness should have increased as protein content (Sissons *et al*., 2005) and its amylose content increased due to fortification (Gianibelli *et al*., 2005). Sissons *et al*. (2005) showed that gluten content increased spaghetti firmness with no consistent trend relating to glutenin/gliadin composition. Sharma *et al.* (2002) and Gianibelli *et al.* (2005) found cooking loss decreased in spaghetti with a low amylose content. However, Wood (2009) suggested that the protein–polysaccharide matrix may be responsible for the retention of amylose during spaghetti cooking and not necessarily the starch composition. In addition, pasta surface stickiness is believed to be influenced by both the surface structure of the spaghetti strand and starch exuded onto the strand surface during cooking. Lowering the amylose content of spaghetti has been shown to increase stickiness (Sharma *et al.*, 2002; Gianibelli *et al*., 2005). Furthermore, increasing the protein content of pasta has been associated with decreased stickiness (Sissons *et al*., 2005). Since cooking loss, stickiness and firmness all decreased with the addition of besan chickpea flour, Wood (2009) suggested that gluten may have little effect on the retention of amylose and other carbohydrates during cooking. The protein–polysaccharide matrix as a whole may be more likely to influence spaghetti quality in terms of firmness, stickiness and cooking loss. Therefore, Wood (2009) reported on the understanding of the underlying mechanisms of pasta quality: i) gluten content/ composition appears to be more important than protein content for pasta firmness; ii) the protein–polysaccharide matrix appears to be more important than the starch composition for cooking loss; iii) supportive of previous findings, increased protein and amylose contents are associated with decreased pasta stickiness; iv) cooking loss and stickiness are not necessarily as strongly related as commonly believed. Chickpea-fortified spaghetti retained firmness much better than durum after refrigeration. A marketing advantage may exist if this desirable firmness is retained when blended pasta is subjected to canning, microwave reheating and inclusion in soups (Wood, 2009).

Furthermore, spaghetti containing 25% chickpea flour had a significantly lower glycaemic index than traditional durum spaghetti (Goñi and Valentín-Gamazo, 2003). Lysine content increased by 64 and 182% in the 15 and 30% blends, respectively, whilst the total protein content and the content of most amino acids increased with chickpea fortification (Wood, 2009). A report by Sabanis *et al.* (2006) investigated 5–50% inclusion of chickpea flour in durum lasagne and found that the physical properties of the dough were improved; however, processing, handling and cooking characteristics deteriorated with the higher substitution levels. Another study investigated the incorporation of 5–30% pulse flours into spaghetti and found that firmness and colour intensity increased, while overall quality decreased (Zhao *et al.*, 2005). Spaghetti production above a level of 30% fortification was not undertaken because fortification made the dough particles increasingly sticky, causing them to aggregate during mixing and made extrusion to produce the spaghetti increasingly difficult (Wood, 2009).

A research on the quality of spaghetti has been done and shows that pasta containing the flour of the Mexican common bean decreases in cooking quality as a result of function of the bean-flour substitution, while the total phenols content (TPC) increases (Gallegos-Infante *et al*.,2010). Moreover, Gallegos-Infante *et al.* (2010) proved that composite spaghetti pasta is darker in colour after they found that their pasta with more bean flour was darker. Another study by Martín-Esparza *et al*. (2013) reported a darker colour was obtained in composite pasta samples due to tiger nut flour brown aspect, the colour differences occurring apparent during cooking. Thus, the addition of pasteurized liquid egg into the formulation helps to reduce these undesirable effects. The incorporation of tiger nut flour into fresh tagliatelle, along with egg, seems to be a good option for obtaining high-fibre pasta (>6%) (Martín-Esparza *et al*., 2013).

Noodles are an important food throughout the world, especially in Asian countries such as China, Korea, Malaysia, the Philippines and Thailand (Akanbi *et al.*, 2011). Like Italian pasta, Asian noodles vary in width, however they are usually served long and uncut as this symbolizes a long life in Chinese tradition (Parkinson, 2014). Almost 40% of wheat products in Asian countries are consumed in the form of noodles (Miskelly, 1993). Li *et al.* (2011) proved that supplementing salted noodles with 15% (w/w) purple yam flour produced equal sensory properties in the overall acceptability of the noodles. However, the addition of yam flour decreased the extensibility of the dough, with increases in the proportions from 5 to 20%. The substitution of wheat flour by yam flour resulted in a decrease in gluten; thus, the binding structure of dough became weak. Based on the investigation report by Sabanis *et al.* (2006), the addition of water to buckwheat flour can also cause rutin to easily degrade into quercetin, which has a bitter taste. Furthermore, it has been reported that the performance of flours and starches in oriental noodle processing is mainly influenced by particle size, pasting properties, and swelling power (Crosbie *et al.*, 1992).

The disadvantage of adding cassava flour to noodle dough is the low quality of the resultant cooked noodle as shown by increased cohesiveness, adhesiveness, and viscosity (Hidayat, 2006). However, Husniati and Anastasia (2013) reported the improved quality of cooked noodles prepared from wheat and fermented cassava flours with a ratio of 80:20, with glucomannan fortification chieved at 2.0−2.5% (w/w). In general, the addition of glucomannan to wheat-cassava noodles enhanced its tensile strength. It is suggested that the reduced tensile strength in control wheat-cassava noodles is caused by the decreased amount of gluten, which is required to create the elasticity of the noodle dough (Husniati and Anastasia, 2013). As a result, the addition of glucomannan did not enhance the cohesiveness and did not reduce the adhesiveness of the wheat-cassava noodle (Husniati and Anastasia, 2013). A study by Tang *et al*. (1998) exhibited a positive effect of gluten on the cohesiveness of noodles. Gluten also binds water which helps to suppress noodle adhesiveness.

Plantain noodles with more xanthan gum have a longer cooking time with a lower cooking loss. Although the effect of xanthan gum on the cooking time and loss has not been evaluated, after each time of cooking, the plantain noodles with 3.5% xanthan gum were characterized by statistically significant lower cooking losses than the noodles with less xantham gum (Ojure and Quadri, 2012). In addition, the quality of plantain noodles with xanthan gum is fairly good in respect of their firmness, smoothness and stickiness of the noodles (Ojure and Quadri, 2012). In addition, Lee *et al.* (2008) in their study on the addition of alginate to noodles, found it created the need for increased force to cut the noodle. Thus, the possibility of using structuring agents (hydrocolloids) in order to reinforce pasta structure, which could minimize deterioration of pasta cooking quality, should be analysed (Martín-Esparza *et al.*, 2013). In terms of nutrition, much research has been carried out incorporating legume flour (Hou and Kruk, 1998) and barley flour enriched with β-glucan (Miskelly, 1984) in the production of pasta and noodle products. In addition, Collado and Corke (1996) also reported that sweet potato, potato and waxy corn have been used to improve the eating quality of white salted noodle, which is common in Japan.

Conclusion

Through this review, there have been a lot of interesting findings and insights. Using composite flours may be advantageous in developing countries – for example, in Malaysia, where they have adequate technology and a lot of raw botanical sources – whereas the development of such blends could lead to improved utilization of indigenous food crops in countries where the import of wheat flour is a necessity. Composite flour shows good potential for use as a functional agent in bakery products, therefore the evaluation of the functionality of composite flour in test baking should be performed to ensure an increase in the use of composite flour made from many different raw materials in future. At the same time, development and consumption of such functional foods not only improves the nutritional status of the general population but also helps those suffering from degenerative diseases associated with today's changing lifestyles and environment. There is also the need to adjust the mixing ingredients and baking techniques in order to improve the composite bakery qualities. Much effort is needed to find the optimization of composite flour used for any bakery products by mixing different types of crop flours to maximize the composite bakery quality using the mixture response surface methodology. In terms of baking technique, the basis for further tests with varying doses of structural agents, for example hydrocolloids, emulsifiers, proteins, enzymes, starches, and fats and oils, is important. In addition, the effects of the method of processing, such as toasting, boiling and fermentation of flour, could be used to improve rheology properties of composite bakery products. New discoveries can be made in the future, based on the data obtained, and more food products can be developed for domestic markets.

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