Potential of Bambara groundnut in improving food and nutritional security: A review

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Abstract

Bambara groundnut (Vigna subterranea) is a pulse that is drought resistant and composed of healthy nutritional components, though it remains underutilised. The review evaluated the potential of Bambara groundnut in improving food and nutritional security in Sub- Saharan Africa addressing issues of malnutrition. Bambara groundnut contains protein (19 - 25%), fat (4.5 - 7.4%), ash (3.2 - 4.4%), carbohydrate (49.0 – 63.5%), fibre (6.4%) and minerals (magnesium, zinc, iron and potassium). Ripe seeds of Bambara groundnut can be milled into a flour that can be used to make biscuits and/or otherwise mixed with cereals and boiled to make porridge. The flour has also shown potential as a composite in bread production. However, despite a high protein content, some of the food products formulated from Bambara groundnuts are not acceptable based on sensory evaluation especially taste and flavour. Findings also suggest that the processing method influences the sensory attributes and bioavailability of nutrients in the formed products. Hence, these should be considered during the formulation of the various food products from Bambara groundnut. Formulating various products from Bambara groundnut will increase its consumption hence reducing the burden of food and nutrition security.

Key words: Bambara groundnut, food security, nutritional composition,

ISSN 2518 - 4334

Introduction

The shift by consumers to plant-based foods is expected to increase due to rapid growth in the awareness of the environmental impacts of livestock and the health risks implications resulting from overconsumption of meat (Monnet et al., 2019). Hence, there is a demand for more plant-based diets and energy efficient processing (Monnet et al., 2019) which is a sustainable approach to produce proteins, other nutrients and protein-enriched products (Assatory et al., 2019). Plant proteins constitute an important source of essential amino acids required for good health and are commonly used as protein supplements (Assatory et al., 2019). The amino acid composition of the food protein represents its nutritional quality (Boye et al., 2010), whilst the amino acid sequence together with the length of the peptide determine its structural and functional properties (Bessada et al., 2019).

According to Mazahib et al. (2013), Bambara groundnut (Vigna subterranea) is a legume which belongs to the family of Fabaceae. It is regarded as the third most important crop in Africa, but it is recognised as a snack and not a lucrative cash crop due to its low status (Oyugi et al., 2014). In addition, Bambara groundnut has been termed a woman's crop hence it has been given less value and priority in land allocation in Zimbabwe (Alercia, 2013; Forsythe et al., 2015; Mubaiwa et al., 2018). Currently, Africa is faced with food security and global warming threats therefore, Bambara groundnut might be a crop of hope to alleviate these challenges because of its drought resistant features (Basu et al., 2007; Hillocks et al., 2012). In addition to being tolerant to drought, Bambara groundnut is also tolerant to pests and diseases and has the ability to produce a reasonable crop when grown on poor soils (Collision et al., 2000; Eltayeb et al., 2011; Murevanhema & Jideani, 2013).

Bambara groundnut contains sufficient quantities of protein (20.5-26.0%), carbohydrate (50.5-69.3%) and fat (4.3-7.9%) and amino acids higher than that found in most legumes (Arise et al., 2015). It is also a good source of minerals such as iron, potassium, zinc, magnesium, phosphorous and calcium (Hussin et al., 2020; Oyeyinka et al., 2019; Qaku et al., 2020). However, it remains underutilised despite its potential for food security and income generation (Forsythe et al., 2015; Mubaiwa et al., 2018). Besides the nutritional importance of Bambara groundnuts, various problems such as beany flavours, long cooking hours and anti-nutritional factors have been

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reported and these may hinder maximum utilisation of the crop (Honi, 2016). Together with these problems the under utilisation of Bambara groundnut may be due to lack of sufficient research to unlock its potential. Hence, this review focused on evaluating research done on the nutritional benefits, anti-nutritional factors, effects of processing on the anti-nutritional factors and various products from Bambara groundnuts. This was done with the view that maximum utilisation of Bambara groundnut related products has the potential to improve food and nutritional security.

Nutritional composition of Bambara groundnut

Bambara groundnuts have high nutritional qualities, containing 51- 60% carbohydrates and 16 - 25% protein content which is similar to cowpea but slightly lower than soya bean protein (Table 1) (Adegbola & Bamshaiye 2011; Hillock et al. 2012; Murevanhema & Jideani 2013). Arise et al. (2015), reported that Bambara groundnuts contain approximately 63.5% carbohydrates, 27% protein, 7.4% fat and 4.4% ash. Oyeleke et al. (2012) emphasised that the high protein in Bambara groundnut is important for the body to repair and build new tissues.

Table 1: Nutritional composition of Bambara groundnut

Nutrient	Composition
Ash (g/ 100g)	2.0 – 3.6
Crude protein (g/ 100g)	16.2 – 27.0
Crude fat (g/ 100g)	1.6 – 7.4
Carbohydrate (g/ 100g)	54.5 – 69.3
Crude fibre (g / 100g)	1.8 – 12.9

Source: Arise et al. (2015); Adegbola & Bamishaiye (2011); Hillocks et al. (2012); Murevanhema & Jideani (2013).

According to Halimi et al. (2019), Bambara groundnuts has a high mineral content compared to other legumes. Bambara groundnuts have also been reported to be an excellent source of calcium, iron and potassium (Table 2). Bambara groundnuts contain unsaturated fatty acids that appeal to

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consumers from a health perspective. Although it increases the rate of rancidification and oxidation, the use of artificial flavours and preservatives during processing is discarded due to their higher concentration of soluble fibre than any other legume (Oladele, 2013). The total phytosterol content of Bambara groundnuts ranges from 15.9 mg/100 g to 255.2 mg/100 g (Wang et al., 2019). Rawal et al. (2015), reported that the total phytosterol content of Bambara groundnuts is 221 mg/100 g. Phytosterols, like unsaturated fatty acids, have beneficial health effects on the human body, including decreasing cholesterol, regulating the immune system, and preserving the skin from aging. Furthermore, because of their high antioxidant content, they can help prevent cancers (Rawal et al., 2015).

Table 2: Mineral composition of Bambara groundnut

Mineral	Composition (mg/ 100g)
Iron	5.9 – 7.1
Potassium	1240 – 1290
Phosphorous	296 – 320
Sodium	3.7 – 4.8
Calcium	7.8 – 13.5

Source: Adegbola & Bamishaiye (2011); Hillocks et al. (2012); Murevanhema & Jideani (2013).

The major non-essential amino acids in Bambara groundnut protein have been shown to be aspartic acid (146.1mg/g crude protein) and glutamic acid (209mg/g crude protein) (Mune Mune et al., 2011), this is the same as in other legume proteins such as from soya beans (Adebowale et al., 2011, Feyzi et al., 2015) and black bean (Kudre et al., 2013). The principal essential amino acids have been shown to be lysine (80.2 mg/g crude protein) and leucine (102.1mg/g crude protein) (Mune Mune et al., 2011). In a study by Arise et al. (2015) lysine was also found to be high at around 6 g/100g protein almost the same as in soya bean protein (Adebowale et al., 2011). Arginine a conditionally essential amino acid was also found to be high in Bambara groundnut around 7g/100g. In addition, Bambara groundnut is also high in isoleucine, methionine, phenylalanine,

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threonine and valine. According to Ijarotimi & Esho (2009), Bambara groundnut has levels of essential sulphur containing amino acids higher than that those found in most legumes. Bambara groundnut can therefore be used as a complementary protein in cereal grains (Boye et al., 2010).

The functional properties of Bambara groundnut are essential for the successful utilisation of the crop. Functional properties are the intrinsic physicochemical characteristics affecting the behaviour of food commodities during different processing methods (Aremu et al., 2007). One of the main functional properties necessary in protein ingredients is gelation (Eltayeb et al., 2011), among others such as emulsion, protein solubility, water and oil absorption capacity (Aremu et al., 2007). Bambara groundnuts can therefore be mostly utilised in provision of protein in areas where animal protein is deficient or expensive (Ijarotimi & Esho., 2009). Bambara groundnuts contain various amounts of nutrients able to provide nutritional benefits that lead to improved nutrition, and food security. Due to the excellent nutritional value in Bambara groundnuts, Ogundele et al. (2017) classified Bambara as a complete food. However, though Bambara groundnuts are a good source of nutrients they also contain anti-nutritional factors that can inhibit the bioavailability of some of these nutrients.

Anti-nutritional factors

Anti-nutritional factors in Bambara groundnuts

Bambara groundnuts contain levels of anti-nutrients such as trypsin inhibitor, phenolic compounds, oxalate, tannic acid, phytic acid and phytin (Ijarotimi & Esho 2009). It has been stated by Unigwe et al., (2017) that the red and brown Bambara groundnuts contain the highest levels of tannins while the cream coloured ones have the lowest. These anti-nutrients are substances that interfere with digestive processes and prevent the absorption of essential nutrients, particularly minerals, in the body when they are consumed in foods containing them. Anti-nutrients, according to Attaugwu et al. (2016), reduce the efficient utilization of nutrients, negatively affecting their bioavailability. Anti-nutrients have been shown to reduce amino acid bioavailability by up to 50% (Hamili et al., 2019).

The polyphenolic compounds in Bambara groundnuts reduces the bioavailability of minerals and proteins by forming refractory compounds (Unigwe et al., 2018). Dubey & Matel (2018), reported

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that phytate and oxalate in Bambara groundnut milk reduce calcium bioavailability thereby preventing it from being absorbed. Additionally, phytate reduces the bioavailability of iron, zinc, and magnesium. Insoluble complexes are formed as a result of the reaction with the cations of minerals (Gibson et al., 2006). Sethi et al. (2016), also agreed that the phytic acid contained in Bambara groundnuts prevents zinc and iron absorption. These anti-nutritional factors need to be reduced so as to improve the nutritional value and increase the effective utilization of the nutrients on the nuts. Bambara groundnuts must be processed (germinating, roasting, soaking and cooking) prior to consumption in order to improve their palatability and nutritional quality. These processes produce changes in nutritional composition and content of bioactive compounds.

Effect of processing on the anti-nutritional factors in Bambara groundnut flour

Heat treatment can reduce the activity of trypsin inhibitors and increase the digestibility and protein utilization. Heat treatment is an effective means of inactivating the heat-labile anti-atrophic factors of Bambara groundnut. Cooking, autoclaving, pressure cooking, extruding and microwaving are some of the heat treatments commonly applied to Bambara groundnuts before consumption (Mazahib et al., 2013). Literature also suggests that simple treatment methods such as soaking, boiling, and roasting can remove or reduce phytic acid in Bambara groundnut. Mazahib et al. (2013), also supported that soaking and cooking increases the reduction of tannins, phytic acid and polyphenols in Bambara groundnut. The bindings of formed complexes and anti-nutrients are broken by thermal treatments. Boiling degrades the oxalate and improves calcium absorption (Gibson et al., 2006).

Fermentation achieved through addition of culture bacteria is another means of enhancing bioavailability for example in Bambara groundnut milk. Short-chain fatty acids are formed due to the addition of the bacterial culture these enhance the solubility of bioavailable calcium, hydrolysis of glucoside linkage, synthesis of vitamins, and production of bioactive peptides. Probiotics such as lactobacillus in Bambara groundnut milk with estrogenic activity increase the bioavailability of calcium by hydrolysis of glycoside bonds in the intestines (Dubey & Matel, 2018). Furthermore, fermentation promotes the development of organic acids, which enable the production of soluble ligands with trace minerals found in the gastrointestinal system. As a result, some minerals, particularly zinc and iron, are better absorbed (Gibson et al., 2006). The phytase enzyme, present

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in lactic acid, bacteria, and yeasts, is responsible for phytate hydrolysis. In fermented Bambara groundnut milk, starter cultures such as bacteria and yeasts increase isoflavone bioavailability, enhance protein digestion, and increase calcium solubility. In fermented Bambara groundnut milk, calcium, magnesium, riboflavin, and niacin were found to be in higher proportions than in unfermented Bambara groundnut milk (Rekha & Vijayalakshmi, 2010). Thus, the anti-nutrient content decreases, lead to improved bioavailability and bio accessibility of nutrients, overall health and immunity improve (Rekha & Vijayalakshmi, 2010) thus improving food and nutrition security.

Various products from Bambara groundnut

Bambara groundnut is primarily used for human consumption either when fully ripe or immature. Immature seeds can be consumed fresh after boiling or grilling, as a meal and even mixed with immature groundnuts or green maize (Adegbola & Bamshaiye, 2011). When fully ripe, the seeds are dried and roasted, broken into pieces, boiled, crushed and eaten as a relish. Murevanhema & Jideani (2013) states that Bambara groundnut fresh pods can be boiled with salt and eaten as a snack or roasted and crushed to make soup. Bambara groundnut seed are boiled overnight with corn in Kenya, then soaked, crushed, and fried into stews (Heller et al., 1997). Fresh pods are cooked with salt and pepper as snacks in some West African countries (Hillocks et al., 2012). In Ghana, the seeds are soaked overnight and then cooked till porridge is formed.

Recently studies have deduced Bambara groundnut potential for the development of various food products such as biscuit and cake production, vegetable milk and yoghurt reported by Falade et al. (2014). The successful performance of Bambara groundnut flour as a food ingredient depends on the functional characteristics and sensory qualities that it imparts to products. In addition, the ripe seeds can also be milled into a flour that can be used to make biscuits and/or otherwise mixed with cereals and boiled to make porridge (Barimalaa et al., 2005, Adegbola & Bamshaiye, 2011). Bambara groundnuts can be mixed with peanut butter and eaten with maize, but coarse Bambara groundnuts are processed into porridge. Other authors emphasised that Bambara groundnuts can be used to fortify other traditional foods. Ogi is a fermented sorghum porridge with Bambara groundnuts flour fortified at a ratio of 60:40 (Olufemi, 2019), fortification of Bambara groundnut flour improves nutritional value. Fufu is a cassava fortified with Bambara groundnut flour

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(Olapadeet al., 2014). Dried and ripe Bambara groundnuts can be milled into flour and used to make cakes or mixed with granola to make porridge (Oyelekeet al., 2012).

The flour has also shown potential as a composite in bread production (Alozie et al., 2009). In Ghana, Bambara groundnut flour is used to make brim (Nti, 2009). Bambara groundnut flour is mixed with water and seasoned with salt to make a firm dough, also known as the fermented spiced awadawa in western Africa. Bambara groundnut flour is also used to make bread in other parts of Africa, such as Zambia (Brough et al., 1993). Bambara groundnut flour can be used to make mixed flour and can be incorporated into noodles production. Other studies have found that fortifying meals with Bambara groundnut flour can easily achieve increases in protein (Honi, 2016). The authors hypothesized that adding Bambara groundnut flour to the noodles could correct nutrient imbalances in children consuming them.

According to Han et al. (2010), legumes such as Bambara groundnut are gluten free and have low glycemic index, a characteristic that benefits people with diabetes, cardiovascular disease and celiac disease. According to previous studies, Bambara groundnuts can compete with or replace other conventional flours in a variety of processed products (Massawe et al., 2005). The uses of Bambara groundnut flour in the supplementation of other flours such as wheat flour have been reported in various studies (Nwosu, 2013). In the studies, the blended flours were used to develop biscuits and the results showed that the biscuits were high in protein. With Bambara groundnut incorporation, the diameter of the biscuits was increased and there was an improvement in the flavour and texture of the biscuits. These changes were linked to the changes in the functional properties of wheat flour when Bambara groundnut flour was added. In another study by Alozieet al. (2009), Bambara groundnut was used to develop bread and the resultant bread exhibited improved protein, ash and crude fibre content. Erukainure et al., (2016), state that the development and improvement constancy time was observed with Bambara groundnut incorporation in wheat flour. Also, an increase in bread specific volume was observed in another study with Bambara groundnut flour inclusion (Abdualrahman et al., 2012). Thus the applicability of Bambara groundnut flour in bread production as well as in improving the properties of bread when used as a composite flour. Such use will increase the consumption of nutrient rich foods hence reducing issues to do with food and nutrition insecurity.

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Murevanhema & Jideani (2013) found that Bambara groundnuts may be used to make vegan milk that is comparable to soy milk. Bambara groundnut milk can be prepared in the same way as soymilk and is often used as weaning milk in many countries (Brough et al., 1993). It is also used for religion (vegetarians) and health reasons (people who are allergic to milk protein, who have a diet free of cholesterol, lactose, and dairy products) (Granato et al., 2010). Current interest in Bambara groundnut milk stems from the fact that milk and dairy products are too expensive for low-income earning people (Lawal et al., 2007). There is an increasing need to switch to vegetable milk as an alternative to animal milk. Also, some people have an allergic reaction to animal milk due to lactose intolerance whilst some just choose a different lifestyle. Saturated fats in full-fat milk have also been linked to higher cholesterol levels (Miller et al., 2000), prompting some people to switch to plant-based milk for a healthier diet. Bambara groundnut milk is a low-cost, high-nutritional-value product. In this regard, researchers have concentrated on products derived from fermentation, such as yogurt, buttermilk, and ripened cheese analogues (Lawal et al., 2007). Lactose intolerance, cholesterol content, and allergenic milk proteins are the key downsides of dairy consumption, making the development of new probiotic products essential (Granato et al., 2010). Brough et al. (1993) looked into the feasibility of creating Bambara groundnut milk for local consumption, and they found that there was a lot of potential for Bambara groundnut milk plant-based yoghurt. Milk from Bambara groundnuts was rated higher in acceptability than milk from other legumes such as soybean and cowpea. Generally, there has been reported scarcity of milk supply mostly in developing countries partly due to the increasing population (Salami et al., 2020; Onweluzo & Nwakalor, 2009). In addition to this, there has been increasing concerns on cow milk allergies, lactose intolerance, calorie concern and the prevalence of hypercholesterolemia (Jeske et al., 2018, Supavititpatana et al., 2010) thus the continuous search for alternative sources of milk. The use of Bambara groundnuts as a milk source will help meet the burden of malnutrition hence impacting food and nutrition security.

Conclusion

Bambara groundnut is a drought resistant legume, tolerant to pests and diseases and has the ability to thrive in poor soils. The legume has a high nutritional value protein (19 - 25%), fat (4.5-7.4%), ash (3.2-4.4%), carbohydrate (49.0–63.5%), fibre (6.4%) and minerals (magnesium, zinc, iron and

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potassium). The anti-nutritional factors in Bambara groundnut can be reduced by processing (soaking, autoclaving, roasting, fermentation or boiling) and the bioavailability of nutrients improved. Ripe Bambara groundnut can be milled into flour to make a number of products that can be consumed by people of all age groups. These products include porridge, biscuits, bread, milk and yoghurt. An increase in the production of products from Bambara groundnut protein can help improve food and nutrition security in developing countries. More studies are needed to improve the sensory properties of Bambara groundnut products.

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