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Green banana: new alternative for gluten-free products

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ABSTRACT: Green bananas exhibit high nutritional value and interesting technological characteristics. The aim of this study was to perform a literature review on green banana and its possible use in the food industry, especially concerning the gluten-free market. A literature search was carried out for articles published between 2003 January and 2013 March, using the electronic databases: Scielo, Lilacs, Pubmed and Scopus. Studies pointed out good results with the use of green banana and its derived products in food production in general. There is still not much research about the use of green banana in gluten-free products, but available data suggest it might be an innovative strategy with many benefits to the food industry and consumers who are on a gluten-free diet.

INTRODUCTION

Bananas are a type of fruit produced and consumed worldwide. Green bananas display high nutritional value, representing a good source of resistant starch, phenolic acids, minerals and vitamins which are important for human health(1). Unfortunately, about one-third of all bananas harvested is lost since it is a climacteric fruit and also because the population in general have the habit of consuming only ripe bananas. This great amount of wasted green bananas could be directed to the food industry, thereby improving bananas economics. That would also be an important strategy to alleviate the environmental problem presented by banana waste(2). Despite all that, its use is still very limited by the food industry. It is considered a sub product of low commercial value and insignificant industrial advantage(1).
With the arise of the gluten related disorders, some of which have been known for a long time – such as celiac disease and dermatitis herpetiformis – and others only recently identified – as gluten sensitivity – it has become very important to expand the gluten-free food market(3). The use of green banana and its derived sub products could be an interesting alternative for wheat or gluten replacement in food(1).
Possible applications for culled bananas could be flour production or banana pulp production(2). Beyond that, green bananas can be used for production of biomass(4), banana flour and banana peel flour(5). The use of green banana in the production of gluten-free food could help improving nutritional, sensorial and technological quality of these products, as well as providing more accessible products – with a lower cost – to the intended public (1).
Considering all that, the aim of this study was to perform a literature review on ripe and green banana and investigate its possible use in the food industry, including the production of gluten-free food.

METHODS

A search of articles that discuss green and ripe banana, its different sub products and the technological characteristics that could justify its use in the production of gluten-free food was performed. The literature search was carried out for articles published between 2003 January and 2013 March, using the electronic databases: Scielo (Scientific Electronic Library Online), Lilacs (Latin American and Caribbean Centre on Health Sciences Information), Pubmed (US National Library of Medicine – National Institutes of Health) and Scopus –which includes 100% of the Medline (National Library of Medicine) publications database.
The keywords used were "green banana", "banana", "resistant starch", "gluten", "gluten-free" and "celiac disease". The search was conducted in English, Portuguese and Spanish, using the corresponding terms. The descriptors "green banana" and "banana" were used in combination with the other keywords or used alone.
Inclusion and exclusion criteria were then established. The inclusion criteria were: (i) original articles; (ii) articles in English, Portuguese or Spanish; (iii) studies about the nutritional composition of banana and green banana; (iv) studies about the sub products of bananas; (v) studies about the technological characteristics and functional properties of banana compounds; and (vi) studies about the use of banana and its derived products in the production of gluten-free food. The exclusion criteria were: (i) review articles; (ii) articles in languages other than the ones mentioned; (iii) articles that were not complete. The articles that met the inclusion criteria were then selected.

RESULTS AND DISCUSSION

Banana and green banana: nutritional composition

Banana (*Musa* spp.) is the most consumed fruit in the world, with many available varieties (6). It contains high amounts of potassium, pro vitamin A carotenoids, vitamin B1, B2 and C (7) and many antioxidants, especially catechin, epicatechin and gallocatechin. The presence of bioactive amines has also been reported in bananas (6). Despite the differences in the nutritional composition between varieties, bananas in general represent a good source of magnesium, copper and manganese (8).
Some authors recommend promoting the consumption of banana-based food to help reducing vitamin A deficiency in countries with high prevalence of hypovitaminosis. It has been reported that one unit of some *Musa* cultivars

can provide up to half of the total human daily vitamin A requirement through its provitamin A carotenoids content. A study from Africa showed that the bioaccessibility of provitamin A carotenoids from boiled banana are in general higher than other starchy food rich in carotenoids, like orange-fleshed sweet potato (9).
The different maturity stages of banana determine though significant differences on physicochemical characteristics (10). During the process of banana ripening, changes in appearance, texture and chemical composition of the fruit happen. Water migrates from the peel to the pulp and starch is degraded, which can soften the pulp. Besides that, there is also production of low molecular weight sugars, such as glucose, sucrose and fructose (6).
The unripe stage of banana is characterized by a high content of starch, of which 20-25% is found in the pulp of the fruit. During the climacteric, polysaccharides are degraded and most of it is converted into soluble sugars (table 1) (11).

Parameters (%)	Green banana	Ripe banana
Protein	5,3	5,52
Fat	0,78	0,68
Fiber	0,49	0,3
Ash	3,27	4,09
Resistant starch	62	2,58
Saccharose	1,23	53,2
Soluble sugars	0,24	33,6

Adapted from Lii *et al.* (1982) (12).

Table 1.Chemical composition of banana in different maturity stages. Adapted from Lii et al. (1982) (12).

Other authors have reported different values for starch and soluble sugars in green and ripe banana. In the study by Adão & Glória (2005), starch content was 15,7% in green banana and 3,4% in ripe banana, while soluble sugars content was 1,26% and 14,3%, respectively (6). Peroni-Okita (2010) found 22% for starch content in green banana and 5% in ripe banana. For soluble sugars, the authors found 0,6% in green banana and 13% in ripe banana (13).
The differences in banana composition between studies are probably due to the maturity stages subcategories, variety of the fruit, cultivation and ripening conditions (6).
Green banana contains great quantity of total phenols and flavonoids, such as catechin, epicatechin, gallocatechin, dopamine and tannin. Among the antioxidant compounds, gallocatechin and dopamine are most abundant in green banana pulp (7).
Moreover, green banana might be considered a source of resistant starch. Resistant starches defined, according to EURESTA (European Research Project on Resistant Starch), as "the sum of starch and products of starch degradation not absorbed in the small intestine of healthy humans"(14). Resistant starch exhibits physiological effects similar to those of dietary fiber (15).
Therefore, the consumption of unripe bananas – although not very common in some countries – can generate many beneficial effects on human health (16).

Banana derived products: banana flour, biomass and banana starch

Banana flour

An interesting strategy to increase utilization of banana is to produce banana flour. Green banana flour displays high total starch, resistant starch and dietary fiber content (5). Unripe banana flour also represents a source of antioxidants compounds (16).
The presence of these functional components makes regular consumption of green banana flour beneficial to the human health (5). It might be used with the purpose of preventing or reducing high levels of cholesterol, constipation, diverticulitis and even colon cancer (17). It may also be helpful in diabetes control, since it is rich in indigestible carbohydrates that cooperate with adequate glycemic response (16).
In a study conducted in Brazil, chemical composition and nutritional value of unripe banana flour was evaluated. The results showed high amount of dietary fiber and low content of available starch and soluble sugars. The following phytosterols were identified: campesterol, stigmasterol and β-sitosterol. Mineral, phytosterols, available carbohydrate and total polyphenol contents were low, nevertheless green banana flour revealed moderate antioxidant activity (18).
Bezerra (2013) also investigated the composition of green banana flour. However, the authors evaluated and compared green banana flour produced with and without the peel. The results exposed significant differences between peeled and unpeeled banana flour, in regards to lipid, ash and fiber fractions. The most significant difference was in relation to fiber content, which was higher in unpeeled banana flour. Lipid and ash content were higher in peeled banana flour (17). Despite the nutritional benefits of unpeeled banana flour, it presents a darker color and more astringent flavor when compared to the peeled banana flour. That fact can possibly lead to sensorial losses in food production (5).
The amount of waste from banana peel is expected to grow with the development of industries that utilize green and ripe bananas. Considering that, it is important to come up with ways of directing this sub product to other uses (19).
As the pulp, the peel of bananas can also be used for flour production, as previously mentioned. Banana peel contains high quantity of dietary fiber, mainly hemicelluloses and pectin polysaccharides. Hemicellulose might still be used for the development of gums or hydrocolloids (5).
Although less common, ripe banana flour can also be used in food preparation. It is more suitable, however, for dishes that require sweetness, since it contains high amount of sugar (5).

Banana biomass

Banana biomass can be obtained by cooking green bananas. The cooking process leads to tannins inactivation and thus loss of astringency of the fruit. The final product has a neutral flavor and no odor and so can be used in many different preparations, promoting aggregation of nutrients and bioactive compounds, without compromising sensorial quality of the product (20).
According to Borges (2003), green banana biomass can be produced using the following protocol: i) wash the fruits in running water with neutral detergent; ii) cook the bananas with the peel under pressure for 10 minutes; iii) let the fruits chill; iv) unpeel the bananas; v) homogenize them in a food processor for 5 minutes without adding water. The biomass might be dehydrated and used for the production of flour. It can also be used as starch or fat replacer in food or added to preparations to improve its nutritional value (21).
Many studies have demonstrated good acceptability of products with addition of green banana. Besides good acceptance by consumers, it is important to highlight the nutritional benefits it confers to the product, such as addition/increase of bioactive compounds (22, 23, 1).
Green banana biomass was used by Fazolin (2007) in the production of cookies with partial substitution of wheat flour by banana flour. The final product exhibited good acceptance by evaluators of different ages, representing an attractive product with high nutritional value for the food market (22).
In another study, the use of green banana biomass for partial substitution of wheat flour in pasta displayed satisfactory results. The addition of biomass contributed to increase fiber

content and decrease fat. Sensorial evaluation revealed good acceptance in relation to the conventional pasta (24). Moreover, Izidoro (2008) used the pulp in the preparation of mayonnaise. The final product exhibit lower caloric value when compared to the traditional mayonnaise and higher content of potassium, iron, calcium, phosphorus, magnesium and fiber(23).

Banana starch

Starch is the most important source of carbohydrates in food and it represents 80-90% of all the polysaccharides in the diet. There are two types of starch: digestible and resistant starch. The digestible starch is susceptible to the action of amylase, while the resistant starch is not (17).
Since it is not digested in the human small intestine, resistant starch reaches the large bowel and is fermented by bacterial microflora. It generates many beneficial effects on health, such as reduction of the glycemic and insulinemic responses to food, hypocholesterolemic action and protective effects against colorectal cancer (15). Resistant starch is also associated with adequate functioning of the digested tract (18).
In the food industry, starch has great value since it is responsible for many technological properties of processed food products. It exhibits a lot of industrial applications, as thickener, colloidal stabilizer, gelling agent and volume enhancer (17).
Green banana contains high levels of starch, mainly in the form of resistant starch (17). Raw banana flour presents about 75% of starch, of which 3% consists of rapidly digestible starch, 15% of slowly digestible starch and 57% of resistant starch (25). Starch obtained from green banana flour generally exhibits high viscosity and high tendency towards retrogradation, when compared to other starch sources (17).
Zhang & Hamaker (2012) examined the digestibility of cooked banana starch and flour. The results showed that banana starch had lower rapidly digestible starch and higher slowly digestible and resistant starch when compared to starches from corn and potato. It also presented higher pasting viscosity. Hence, cooked banana starch represents an interesting option as a starch additive with relatively balanced energy release and a good proportion of slowly digestible and resistant starch (25).
Considering that, it is possible to assume that banana starch may be a functional native starch thickener that resists heat and shear to a degree usually associated only with chemically modified starches (25).
The nutritional/nutraceutical potential of green banana starch has been discussed by many authors (15) and its use might be a tendency in the next few years.

Banana in the food industry

The starch content of unripe banana pulp and the high levels of cellulose, hemicellulose and lignin might enable the production of banana flour foodstuff with attractive chemical and functional characteristics. Besides that, other interesting aspects are the low cost of the fruit (15) and the fact that it is easily transported and can be stored for a longer period, representing a potential product for industrialization (18).
Some effort has been made towards the development of products using green banana flour in order to increase resistant starch and fiber content in food. Banana flour has already been used as in ingredient in the production of bread, biscuits and spaghetti (17).
Agama-Acevedo (2009) investigated the use of green banana flour in addition to semolina to produce spaghetti. Adding this ingredient generated decreased diameter of cooked spaghetti, increased water absorption and

intensification of color. Hardness and elasticity of spaghetti were not affected by banana flour. On the other hand, adhesiveness and chewiness increased as banana flour level in the blend augmented. Despite all that, there were no differences in preference by consumers between the spaghetti prepared with or without the green banana flour, showing that the addition of banana flour to spaghetti without detriment of consumer preference might be a possibility (26).
Ovando-Martinez (2009) also studied the use of green banana flour to produce spaghetti. The results pointed out that addition of banana flour to the wheat formulation increased the indigestible fraction and the content of phenolic compounds in the spaghetti. The banana flour spaghetti showed increased antioxidant capacity (27).
In another study, green banana flour bread was prepared and then compared to wheat flour control bread. The chemical analysis revealed a product with higher protein and total starch content. The dietary fiber represented 14,5% of the constituents of the product. Green banana flour bread showed higher resistant starch and indigestible fraction content and, consequently, significantly lower glycemic index (15).
Ramli (2009) investigated the use of green and ripe banana pulp and peel flour as functional ingredients in noodles by partially substituting wheat flour. Noodles prepared with banana flour presented a darker color than the wheat control noodles, which is an undesirable alteration. On the other hand, the results also pointed out that partial substitution of wheat flour with banana flour generated noodles with higher tensile strength and elasticity. Those characteristics were observed with more intensity in the preparations obtained with ripe banana pulp flour rather than those obtained from banana peel flour (19).
Choo & Aziz (2010) also evaluated the use of green banana flour in noodles. The addition of green banana flour (30%) significantly improved the antioxidant properties of noodles in terms of the total phenolic content and inhibition of peroxidation, when compared to the control product. The fiber content was also significantly higher. Moreover, sensory

evaluation showed that the quality of banana flour noodles was comparable to the wheat control noodles (7).
In a study from Brazil, instant noodles were prepared with the addition of 10% of green banana flour to a wheat base formulation. The use of green banana flour led to rheological changes in the dough, but a sufficient degree of extensibility and elasticity was achieved, allowing the production of a functional instant noodle. Furthermore, the lipid content was significantly reduced and the resistant starch content was increased. Despite the change in color of the product and the reduced firmness it presented, the production of instant noodles with addition of green banana flour was possible, and it displayed a better nutritional profile (28).
Green banana flour has also been tested in the production of cookies. Agama-Acevedo (2012) evaluated cookies prepared with partial substitution of wheat flour by banana flour, in different proportions, and compared to a 100% wheat flour control product. Cookies with the green banana flour presented higher moisture content, higher dietary fiber and resistant starch and lower protein content than the control sample (16).
Recent studies have been showing the applicability of green banana in the food industry. Unripe bananas have been used in the production of different types of items and the results have been good.

Banana and the gluten-free market

The treatment for celiac disease (CD) consists of complete exclusion of gluten from the diet. That is a complicated task because wheat and the other cereals that contain gluten are widely consumed around the world and gluten-free products may be difficult to find (29, 30).
The use of banana in gluten-free products has scarcely been exploited. There are only two records in the literature so far about the use of bananas in the development of gluten-free products.
In a study conducted in Brazil, pasta formula developed using green banana flour was compared to traditional pasta made from wheat. The sensorial analyses revealed no significant differences between the modified and the standard samples in terms of appearance, aroma, flavor and overall quality. As a matter of fact, the modified sample presented greater acceptance than the standard sample (1).
Furthermore, the ash content verified in the green banana flour pasta was 52,7% higher than the observed in the standard sample, evincing a better nutrient profile, which can be beneficial in treating nutritional deficiencies caused by CD (1).
The green banana flour pasta also exhibit reduced caloric value when compared to other gluten-free pasta available in Brazil, made from ingredients such as rice flour and quinoa (1). These results support the hypothesis that the use of green banana flour may be an interesting solution for substitution of wheat in gluten-free pasta. It is a low cost product with good acceptance by CD patients and no adverse reactions as verified in this study (1).
The use of banana flour has also been tested in gluten-free muffins. NG (2012) investigated the effects of substituting rice flour with banana flour, in different proportions. There was a reduction of volume as the percentage of banana flour increased. In regards to texture of the samples, an increase of hardness, chewiness and gumminess was also observed with increase of banana flour content (31).
Sensorial evaluation revealed that the 25% banana flour muffins were the most liked. The results also pointed out that there were no significant differences between the 50% banana flour muffin and the control muffin. This study demonstrates that rice flour substitution up to 50% with banana flour can lead to the production of acceptable gluten-free muffins, with increased health benefits of resistant starch, and no adverse reactions to the celiac individuals (31).

CONCLUSION

The expansion of the gluten-free market is extremely important to individuals presenting CD or any of the gluten related disorders. Development of alternatives by the food industry could contribute to diet compliance and consequent quality of life.
Green banana flour is a low-cost ingredient with high nutritional value and its use can help minimizing banana waste. Many studies have reported good results with the use of green banana flour in partial substitution of wheat flour. Currently, it is necessary to evaluate the use of this ingredient in complete substitution of wheat flour or in combination with other gluten-free cereals, in order to provide more options for CD patients.
There is evidence that green banana flour might be an innovative strategy with many benefits to the food industry and consumers.

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