

The effect of Gamma Irradiation on the Nutritional Properties of Functional Products of the Green Banana

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Abstract—Banana is one of the most consumed fruits in the tropics and subtropics. Brazil accounts for about 9% of the world banana production. However, the production losses are as high as 30 to 40% and even much higher in some developing countries. The green banana flour is a complex carbohydrate source, including a high total starch (73.4%), resistant starch (17.5%) with functional properties. Gamma irradiation is considered to be an alternative method for food preservation. It has been performed due to the need of extending the shelf - life of foods, whilst maintaining their safety and avoiding one of the main concerns: the nutrient loss. In this work data about on the effects of ionizing radiation on the physicochemical analysis (carbohydrate, proteins, lipids, alimentary fiber, moistures and ashes) of Brazilian functional products (biscuits and bread) of the green banana pulp are presented. The caloric value was calculated. No significant difference was observed between the samples of irradiated and non - irradiated green banana biscuits with the following determinations: carbohydrates, proteins, alimentary fiber and ashes. Only a small significant difference was found in lipids (macronutrients). The results of physical chemical analysis of the irradiated and non- irradiated green banana bread non- irradiated showed no significant difference with the following determinations: carbohydrates, lipids (macronutrients), moisture, ashes and caloric value. A small difference was found in proteins (macronutrients). Irradiation of functional products (biscuits and bread) with doses of 1 and 3kGy maintained their original macronutrients content, showing good radioresistance.

Keywords—Irradiation, Functional Food, Nutritional value

I. INTRODUCTION

BANANA is one of the most consumed fruits in the tropics and subtropics. Brazil accounts for about 9% of the world banana production. However, the production losses are high as 30 as to 40% and even much higher in some developing countries [1][2]. As the fruits of the banana trees are consumed at green, average ripe and ripe stages, the amount of fruit waste from the peels is expected to increase with the development of processing industries that utilize the green and ripe banana [3]. New economic strategies to increase the use of banana includes the production of products made from banana (peel, pulp and flour), when the fruit is green, and incorporates the products in various innovative products. The green banana flour is a potential ingredient for bakery products containing slowly digestible carbohydrates [4],[5].

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Carbohydrates constitute the main fraction of unripe fruits, of these, from which starch and non starch polysaccharides (dietary fiber) are the major constituents [4],[5].

The green banana flour is a complex carbohydrate source, it includes a high total starch (73.4%), resistant starch (17.5%) with functional properties. Also, the green banana is a source of dietary fiber (14.5%), macronutrients and micronutrients [5].

Resistant starch was defined as the sum of starch and products of starch degradation that are not absorbed in the small intestine of healthy individuals. It has a reduced caloric content and is characterized by physiological effects that make it comparable to dietary fiber. As it was mentioned before, modern food manufacturing methods destroy most forms of resistant starch, making them unsuitable as ingredients in highly processed food systems. This fact gives importance to the production of resistant starch powders that may be used in the formulation of diverse products. Potential applications for such a type of ingredient include breads, tortillas, pizza crust, cookies, muffins, waffles, breakfast cereals, snack products and nutritional bars, as well as low-fat fermented milks [4]-[5].

The potential applications of banana pulp and peel flour depend on their chemical composition, as well as physicochemical and functional properties. The physicochemical properties of the green banana flour are expected to vary according to the stage of ripeness since it is known that the composition of banana changes dramatically during ripening [3]. The green banana flour has been used in the irradiated ready- to- eat foods, such as bread, macaroni and dietary products, among others. The development and use of functional low cost ingredients is widely exploited by the food industry, and in this sense the indigestible carbohydrates and the antioxidant compounds may impact certain functionality and additional health benefits. Therefore, the nutritional/nutraceutical potential of unripe banana starch has been stated by several authors [5]-[8].

One study that compared the antioxidant compounds in banana peel and pulp extracts found that the content of antioxidant compounds, galocatechin. Galocatechin was higher in the peel (158 mg/100 g dry wt) than in the pulp (29.6 mg/100 g dry wt.) [9]. The antioxidant activity of the banana peel extract, against lipid autoxidation, was stronger than that of the banana pulp extract. Antioxidant capacity of a fruit may be due to other antioxidants, such as flavonoids. Total phenolics were more abundant in the peel (907 mg/100 g dry wt.) than in the pulp (232 mg/100 g dry wt.) [9].

Studies on the mature green banana fruit shows that it is rich in amylase-resistant starch, which simulates colony production of short- chain fatty acids and it is used for treating diarrheal diseases.

Green banana diet improves clinical severity in childhood shigellosis and it could be a simple and useful adjunct for dietary management of this illness [10]. Also, the resistant starches are not digested in the human small intestine and are fermented by bacterial microflora in the large bowel, affecting a number of physiological functions and thus having different effects on health, e.g., reduction of the glycemic and insulinemic responses to food, hypocholesterolemic action and protective effects against cancer [5],[11].

In recent years, there has been a considerable interest in the possibility of improving control of diabetic patients by altering the glycemic impact of the carbohydrates ingested. A tool for ranking foods with respect to their potential blood glucose raising is the glycemic index (GI) concept [5],[12]. "Slow carbohydrate" in the diet, although this cannot be regarded as a general rule, a nutritional variable that may be linked to low glycemic index properties is the resistant starch content of a food or complete meal" [12].

Gamma irradiation is considered to be an alternative method for food preservation. It has been performed due to the need of extending the shelf - life of foods, whilst maintaining their safety and avoiding one of the main concerns: the nutrient loss. The need to eliminate undesired pathogens from food products should always be balanced with the maintenance of product quality [13]-[15].

Proteins, fats and carbohydrates are not notably altered by irradiation [16].

The energy of macronutrients which can be metabolized (carbohydrates, lipids, proteins) is unaffected by irradiation at doses up to 10 kGy and even considerably beyond. Essential amino acids, essential fatty acids, minerals, trace elements and most vitamins suffer no significant losses in foods irradiated under conditions of present or potential commercial application. A few vitamins, especially vitamin B1 in the green banana flour, are partially lost. In general, nutrients most sensitive to heat treatment, such as the B vitamins and ascorbic acid, are sensitive to irradiation. This loss can be minimized by choosing the appropriate conditions, particularly the exclusion of air during irradiation and storage [16]-[18]. In this work data about the effects of ionizing radiation on the physicochemical analysis (carbohydrate, proteins, lipids, alimentary fiber, moistures and ashes) of Brazilian functional products (biscuits and bread) made with the green banana are showed. The caloric value was calculated.

II. MATERIALS AND METHODS

A. Biscuits and Breads

This work were used functional biscuits and bread industrialized. The biscuits (50 g packages) contained in their formulation the following ingredients sweet potato, tofu, paprika, clarified butter, whole green banana pulp, linseed, corn starch, cocunut oil, coconut flour, sweet starch, sour starch, baking powder, salt. Bread was prepared with whole green banana flour, corn starch, yeast, oil, eggs, salt and sugar.

Both samples were kept at a refrigerator (4-7°C) before and after irradiation.

TABLE I
THE PHYSICOCHEMICAL ANALYSIS OF BISCUITS

Nutritional Compositional (g/100 g)	Biscuits of green banana		
	0 kGy	1 kGy	3 kGy
Carbohydrates	54.23 ^a (1.81)	59.66 ^a (0.05)	59.62 ^a (0.06)
Proteins	4.16 ^a (0.24)	3.86 ^a (0.03)	3.93 ^a (0.02)
Lipids	27.63 ^a (0.04)	26.52 ^b (0)	26.50 ^b (0.06)
Alimentary Fiber	4.61 ^a (0.02)	4.80 ^a (0)	4.85 ^a (0.21)
Moisture	5.05 ^a (0.01)	2.4 ^b (0.08)	2.21 ^b (0.12)
Ashes	2.81 ^a (0.01)	2.75 ^a (0.06)	2.87 ^a (0.007)
Caloric value (kcal)	482 ^a (8.48)	492 ^a (0.70)	492.5 ^a (0.70)

n = duplicate, ab Medium values followed by the different letters, on the same line, differ significantly from the control- sample at 5% significance (error 5%), (Dunnett Test). () standard deviations.

TABLE II
THE PHYSICOCHEMICAL ANALYSIS OF BREAD

Nutritional Compositional (g/100 g)	Bread of green banana		
	0 kGy	1 kGy	3 kGy
Carbohydrates	57.76 ^a (0.04)	60.09 ^a (1.4)	60.24 ^a (0.17)
Proteins	3.3 ^a (0.04)	3.49 ^b (0.02)	3.34 ^b (0.01)
Lipids	5.9 ^a (0.007)	5.6 ^a (0.12)	5.8 ^a (0.04)
Alimentary Fiber	1.89 ^a (0.007)	1.93 ^b (0.07)	1.91 ^b (0)
Moisture	30.53 ^a (0.06)	29.15 ^a (0.07)	29.97 ^a (0.09)
Ashes	0.58 ^a (0.03)	0.62 ^a (0.01)	0.60 ^a (0.02)
Caloric value (kcal)	297.5 ^a (0.70)	305 ^a (4.2)	307 ^a (0)

n = duplicate, ab Medium values followed by the different letters, on the same line, differ significantly from the control- sample at 5% significance (error 5%), (Dunnett Test). () standard deviations.

B. Irradiation

Irradiation was performed in a ⁶⁰Co Gammacell 220 (AECL) source, dose rate about 1.60 kGy/h at doses of 1 and 3kGy, dose uniformity factor, 1.13. Dosimetric mapping was previously performed by Fricke dosimetry.

C. The physicochemical analyses

The physicochemical sample analyses were carried out in conformity with the methodologies described in IAL [19], with the following determinations: total carbohydrates, proteins, lipids, total alimentary fiber, volatile substances, ashes. The caloric value was calculated. This value was obtained from Atwater conversion factors, with calculation of the nutrients energy: g% lipids x 9kcal; g% proteins x 4kcal and g% carbohydrates x 4kcal [20]. Analysis of variance (ANOVA) was applied with mean comparisons By Dunnet test, at error of 5%.

III. RESULTS AND DISCUSSION

Protein and starch contents were higher in banana flour bread, what is important due to the valuable metabolic role that both nutrients play in our body [5].

However, lipid content was lower in banana flour, an interesting finding taking into account the possibility of formation of amylose-lipid complex. This type of complex has been related with decreased lipid content and an increase of the indigestible fraction of the starch [5].

Total starch was higher in banana flour bread, but available starch was lower. This fact agrees with the possibility of amylose-lipid complex formation during starchy products processing as it was mentioned above. Bread product added with banana flour presented lower available starch (AS) fraction [5].

The product formulated with banana flour exhibited higher dietary fiber content. Fibre-rich cookies have been reported 3.73 and 5.95% [5].

The high ash content of the banana flour had implications in the ash level founded in the bread formulated with this type of flour, since ash content was higher in banana flour bread compared to that without banana flour [5].

The high moisture content in banana flour bread might be related to the high protein and starch composition and low lipid level, since its components are hydrophilic and have the capacity to join more water molecules. Bread with high moisture content has a softer texture than bread with low moisture level; however, the microorganisms growth could be favoured, affecting the stability and shelf-life of the product [5].

That is why the importance of irradiation technology application in food preservation is recommended. Fruits and vegetables are irradiated at low levels, usually less than 1.5 kGy which can reduce the risk of harmful insect pests and microorganisms, is inexpensive, more environmentally sound than using chemical fumigants, and can greatly reduce the waste of fruits and vegetables resulting from spoilage significantly. At this level and depending on a number of factors including the type of product, only minimal changes occur in nutritional and organoleptic qualities [2].

Mexican bread made with wheat flour was irradiated at 1 kGy, using a ^{60}Co source, no changes were detected in moisture, protein and ashes in gamma irradiated samples as compared to those of non-irradiated samples [13].

Taipina et al. [21] reported that no significant differences were observed on the nutritional properties of sunflower whole grain cookies between the samples irradiated and non-irradiated.

There is general agreement that the metabolizable energy of macronutrients (carbohydrates, lipids, proteins) is unaffected by radiation doses up to 10 kGy and even considerably beyond. Usually, macro and micronutrients, the essential amino acids, essential fatty acids, minerals, trace elements and most vitamins do not undergo significant losses in food irradiated under conditions of actual or potential commercial application [17],[22]. When whole-grain cereals (wheat, rice and rye) were irradiated at 0.1 - 1 kGy, no losses of unsaturated fatty acids were observed. Only small losses were found even at the very high dose of 63 kGy [15].

To study the effect of gamma radiation on the shelf-life extension of bananas, in the present study, the fruits were treated with three radiation doses of 0.30 kGy; 0.40 kGy and 0.50 kGy respectively and were stored in a dry place under room temperature conditions ($25\pm 2^\circ\text{C}$ / $80\pm 5\%$ RH) [2]. During the storage period total sugar content of the control was abruptly decreased. On the other hand, the irradiated

samples showed slowly decrease with increasing storage period because of radiation. Total Sugar content of gamma-irradiated banana was found to be decreased abruptly due to inversion of sugar in presence of acid during storage. The reducing of sugar contents of the control were increased sharply due to the inversion of sugar during storage period. The fat content of gamma irradiated banana remained almost unaltered as compared to the control banana and ranged from 0.1-0.25% during the storage period.

In the same study, it was observed that there were no remarkable changes in protein content throughout the storage period and slight variation of protein content was observed at room temperature [2]. As can be seen (table I), no significant difference was observed between the irradiated and non-irradiated samples of green banana biscuits with the following determinations: carbohydrates, proteins, alimentary fiber and ashes. Only a small significant difference was found in lipids (macronutrients) and moisture. The results of physical chemical analysis of the green banana bread irradiated and non-irradiated (table II) showed no significant difference with the following determinations: carbohydrates, lipids (macronutrients), moisture, ashes and caloric value. A small difference was found in proteins and alimentary fiber.

The findings of this study corroborate data from literature. Usually, macronutrients and micronutrients are preserved under certain conditions (temperature, exclusion of air).



Fig. 1 Irradiators Gammacell 220 (AECL)

IV. CONCLUSION

Irradiation of functional products (biscuits and bread) with doses of 1 and 3kGy maintained their original macronutrients content, showing good radioresistance.

The irradiation technology of functional foods may be recommended.

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