Available online at www.sciencedirect.com
ScienceDirect
Food Chemistry 107 (2008) 1515–1521
Food Chemistry
www.elsevier.com/locate/foodchem

Characterization of a fibre-rich powder prepared by liquefaction of unripe banana flour

S.L. Rodríguez-Ambriz [a], J.J. Islas-Hernández [a], E. Agama-Acevedo [a], J. Tovar [b], L.A. Bello-Pérez [a,*]

[a] *Centro de Desarrollo de Productos Bióticos del IPN, km 8.5 Carr, Yautepec-Jojutla, Colonia San Isidro, Apartado Postal 24, 62731 Yautepec, Morelos, Mexico*
[b] *Instituto de Biología Experimental, Facultad de Ciencias, Universidad Central de Venezuela, Apartado Postal 47069, Caracas 1041-A, Venezuela*

Received 8 June 2007; received in revised form 31 August 2007; accepted 2 October 2007

Abstract

The development of nutraceutical ingredients is of current interest for the food industry. A fibre-rich powder (FRP) was prepared by liquefaction of raw banana flour (RBF) and its chemical composition, water- and oil-holding capacity, and antioxidant capacity were evaluated. Total dietary fibre (TDF) was higher in FRP than in the RBF, but the total starch (TS), potentially available starch (AS) and resistant starch (RS) contents were lower in the processed product, since the liquefaction process involves granular disruption and starch hydrolysis, resulting in reduced TS and AS and increased TDF. The reduced RS content is also explained by the loss of granular integrity, which is the main factor responsible for the indigestibility of native banana starch. Total indigestible fraction content of FRP was relatively high, the soluble fraction being lower than the insoluble portion. A very fast reduction of DPPH was observed in the presence of FRP, indicating that polyphenols in this preparation efficiently quench free radicals. Tested at various temperatures, the FRP and RBF exhibited similar water-and oil-holding capacities. The main difference was observed in water-holding capacity at 80 °C, where FRP was less efficient than the raw material, a fact associated with starch gelatinization in RBF treated at that temperature. FRP might be a potential ingredient for development of products with high TDF and indigestible fraction contents, as well as important antioxidant capacity.

Keywords: Banana; Dietary fibre; Functional properties; Antioxidant capacity; Chemical composition

1. Introduction

Banana is an important crop in the tropical and sub-tropical regions of the world. The fruit is either consumed ripe, due to its high sugar content, or unripe, in several indigenous dishes requiring high starch content. In Mexico and other Latin American countries, banana is mainly consumed ripe. For this reason, large quantities of fruits are lost during commercialization as a consequence of deficient postharvest handling. New economical strategies are now considered for banana use, such as the production of banana flour when the fruit is unripe. Several studies have suggested that consumption of unripe bananas confers beneficial effects for human health, a fact often associated with its high resistant starch (RS) content, which ranges between 47% and 57% (Faisant, Gallant, Bouchet, & Champ, 1995). Recently, the preparation of unripe banana flour was described, with 73.4% total starch content, 17.5% RS content and a dietary fibre level of 14.5% (Juárez-García, Agama-Acevedo, Sáyago-Ayerdi, Rodríguez-Ambriz, & Bello-Pérez, 2006). Additionally, unripe banana flour might be an important source of polyphenols, compounds that are regarded as natural antioxidants (Vergara-Valencia et al., 2007).

Nowadays, the development and use of functional ingredients is widely exploited by the food industry, principally those with high dietary fibre levels. Although banana

* Corresponding author. Tel.: +52 735 3942020; fax: +52 735 73941896.
E-mail address: labellop@ipn.mx (L.A. Bello-Pérez).

0308-8146/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodchem.2007.10.007

represents an alternative source of indigestible carbohydrates, mainly RS and dietary fibre, it is important to keep in mind that, when the unripe fruit is cooked, its native RS is rendered digestible (González-Soto et al., 2006). It is also important to stress that the dietary fibre content of this fruit is relatively low compared with other dietary fibre-source fruits, such as: grape pomace, guava, Mexican lime peel, mango peel and *Citrus sinensis* peel (Bravo & Saura-Calixto, 1998; Chau & Huang, 2003; Jiménez-Escrig, Jiménez-Jiménez, Pulido, & Saura-Calixto, 2001; Larrauri, Rupérez, Borroto, & Saura-Calixto, 1996; Saura-Calixto, 1998; Ubando, Navarro, & Valdivia, 2005).

The technology of starch liquefaction has been applied to starch isolated from unripe bananas for producing maltodextrin and glucose syrup (Bello-Pérez, Sánchez-Hernández, Moreno-Damian, & Toro-Vázquez, 2002). In this way, it is possible to eliminate the high starch content present in the fruit and to obtain a fibre-rich powder that may be used in the formulation of diverse functional foods. On the other hand, elevated consumption of fruits and vegetables, or their derivatives, has been associated with minor incidence of chronic-degenerative diseases. This protective effect is also associated in part with antioxidant compounds present in these foods. From this point of view tropical crop fruits, such as banana and mango, are of interest since they contain polyphenols that show antioxidant capacity (Frankel & German, 2006; Machado-Rocha, de Queiroz, Lopes-Ribeiro, Milagres-Campos, & Pinheiro-Santana, 2007).

The aim of this work was to evaluate some chemical and physicochemical properties of a fibre-rich powder prepared by liquefaction of unripe banana flour.

2. Materials and methods

2.1. Banana flour preparation

Commercial hard green (unripe) preclimacteric banana (Musa AAB) fruits were purchased from the local market in Cuautla, Morelos State, México. Fruits were peeled and cut into 1 cm slices and immediately rinsed in citric acid solution (0.3% w/v). The slices were dried at 50 °C, ground using a commercial grinder (Mapisa Internacional S.A. de C.V., México, D.F.) to pass a US 50 (0.028 mm) sieve and stored at 25 °C in sealed plastic containers prior to further analyses.

2.2. Fibre-rich powder preparation

Liquefaction, at laboratory level, was carried out following the method of Flores-Gorosquieta et al. (2004), using a 2-l reactor: a suspension of banana flour in distilled water (20% w/v) was prepared; after adjusting pH to 7.3, the dispersion was gelatinized at 80 °C for 10 min. The gelatinized slurry was cooled down to 70 °C, mixed with α-amylase of *Bacillus subtilis* (Starzyme TE, ENMEX®, S.A., Mexico) (0.2% v/v) and incubated for 3 h at the same temperature. Thereafter, the enzyme was inactivated by acidification to pH 2.0 with HCl. The mixture was then centrifuged at 1700 rpm to separate the insoluble fibre-enriched fraction. This material was dried at 40 °C for 48 h, milled and sieved (50 US mesh) in order to obtain the fibre-rich powder.

2.3. Chemical composition

Moisture content was determined by gravimetric heating (130 ± 2 °C for 2 h) using a 2–3 g sample. Ash and protein were analyzed according to methods 08-01, and 46-13, respectively (AACC, 2000). Total dietary fibre (DF) was evaluated using the 985.29 AOAC method (AOAC, 1999). Total starch (TS) was determined by the method of Goñi, García-Alonso, and Saura-Calixto (1997); in brief, 50 mg of sample were dispersed in 2 M KOH (30 min) to disperse all starch fractions, then samples were incubated with amyloglucosidase (Boehringer, No. 102857, 60 °C, 45 min, pH 4.75), and glucose was determined using the glucose oxidase assay GOD-POD. TS was calculated as released glucose (mg) × 0.9; potato starch was used as a reference sample. Potentially available starch content was measured with the multienzymatic method described by Holm, Bjorck, Drew, and Asp (1986). Resistant starch was measured by the method proposed by Goñi, García-Díaz, Mañas, and Saura-Calixto (1996). The method comprises removal of protein with pepsin P-7012 (Sigma Chemical CO., St Louis MO) at 40 °C, for 1 h, at pH 1.5, incubation with α-amylase A-3176 (Sigma Chemical Co., St Louis, MO) at 37 °C for 16 h to hydrolyze digestible starch; dispersion of the precipitate in 2 M KOH, neutralization and incubation with amyloglucosidase A-7255 (Sigma Chemical Co., St Louis, MO) at 60 °C, for 45 min, at pH 4.75, and colorimetric determination of glucose using a glucose oxidase/peroxidase assay (SERA-PAK® Plus, Bayer de México, S.A. de C.V., Edo. De México). Soluble (SIF) and insoluble indigestible fractions (IIF) were assessed using the sequential pepsin/amylase hydrolysis method of Saura-Calixto, García-Alonso, Goñi, and Bravo (2000). This method has been proposed as an alternative to the enzymatic dietary fibre assays, aiming to include most of the physiologically indigestible part of foods, regardless of their chemical nature.

2.4. Extractable polyphenols (EPPs)

EPPs were extracted from samples using aqueous-organic solvents. The extraction procedure is described elsewhere (Jiménez-Escrig et al., 2001). The supernatants were combined and total extractable phenols were estimated by the Folin–Ciocalteau method (Jiménez-Escrig et al., 2001), using gallic acid as a standard; results were expressed as gallic acid equivalents (GAE).

2.5. Antioxidant activity (DPPH) assay

Antioxidant activity was measured using the DPPH· (2,2-diphenyl-1-picrylhydrazyl) method described by

Soler-Rivas, Espin, and Wichers (2000). The first step of the analysis, i.e. extraction of components with antioxidant capacity, was carried out as described previously (Salinas, Soto, Martinez, Gonzalez, & Ortega, 1999). Then 1 ml of extract and 2 ml of 60 μM DPPH solution in 80% methanol were mixed and immediately the percentage of reduced DPPH·was calculated. Antioxidant activity was reported as percentage of reduced DPPH at different time intervals (0–60 min).

2.6. Water- (WHC) and oil-holding capacity (OHC)

Twenty-five millilitres of distilled water or commercial olive oil were added to 1 g of dry sample, stirred and incubated at 40, 60 or 80 °C for 1 h. After centrifugation, the residue was weighed and WHC and OHC calculated as g water or oil per g of dry sample, respectively (Larrauri et al., 1996).

2.7. Statistical analysis

Results were expressed by means of values ± standard error of three separate determinations. Comparison of means was performed by one-way analysis of variance (ANOVA), followed by Tukey's test ($p \leqslant 0.05$). Statistical analyses were run using the computer SPSS V. 6.0 software (SPSS Institute Inc., Cary NC).

3. Results and discussion

3.1. Chemical composition

The protein level of the control sample (Table 1) (3.4%) resembles that reported previously (3.3%) for banana flour (Juárez-García et al., 2006), those measured in eight different varieties of banana, whose values ranged between 2.5% and 3.3% (Da Mota, Lajolo, Ciacco, & Cordenunsi, 2000) and the content (3.8%) in a banana flour preparation described by Faisant et al. (1995). The fibre-rich powder prepared here from banana flour showed higher protein content (5.3%) than the raw product (BF) (Table 1). Such a result is due to the amylolytic phase of the flour liquefaction leading to the fibre-rich powder, since this process eliminates water-soluble proteins in the supernatant.

Table 1
Chemical composition of banana flour and fibre-rich powder from banana flour (g dry matter)

Sample	Banana flour	Fibre-rich powder of banana flour
Moisture	6.0 ± 0.1^{a}	6.8 ± 0.5^{b}
Protein[A,B]	3.4 ± 0.3^{a}	5.3 ± 0.6^{b}
Ash[A]	4.4 ± 0.1^{a}	2.3 ± 0.1^{b}
Total dietary fibre[A]	10.4 ± 1.4^{a}	31.8 ± 2.1^{b}
Total starch[A]	76.8 ± 1.0^{a}	52.4 ± 1.1^{b}
RS[A]	30.4 ± 0.8^{a}	3.6 ± 0.4^{b}
AS[A]	71.5 ± 1.1^{a}	48.5 ± 1.3^{b}
Insoluble indigestible fraction[A]	44.0 ± 0.5^{a}	61.0 ± 1.2^{b}
Soluble indigestible fraction[A]	8.9 ± 0.4^{a}	8.2 ± 0.8^{a}
Total indigestible fraction[A]	52.9 ± 0.5^{a}	69.2 ± 1.0^{b}
Total soluble polyphenols	2.01 ± 0.03^{a}	2.09 ± 0.08^{a}

Dry matter basis. Values are means of three replicates ± standard error. Values in the same row with the same superscript are not different ($p \leqslant 0.05$).
[A] Dry basis.
[B] $N \times 5.85$.

Fruits are characterized by their contents of certain mineral components. BF exhibited a 4.4% ash content, a value that decreased in the fibre-rich powder (2.3%). It can be concluded that the washing step applied during the liquefaction process eliminated some minerals present in BF. Juárez-García et al. (2006) reported an ash content (4.70%) in BF prepared from banana pulp and peel, similar to the present work. Higher ash contents (2.6–3.5%) were determined in unripe banana flours (Da Mota et al., 2000). However, significantly higher ash levels (between 5.7% and 9.2%), were recorded in grape skin fibre concentrate (Bravo & Saura-Calixto, 1998; Saura-Calixto, 1998).

Total dietary fibre (TDF) in the parental flour was 10.4% (Table 1). A higher TDF level (14.52%) was previously determined in BF (Juárez-García et al., 2006); such a discrepancy may be due to a possible different fruit ripening stage and variable characteristics of the cultivars used in these two studies. Da Mota et al. (2000) determined TDF contents ranging between 6.28% and 15.5% in flours prepared from eight different banana cultivars. A lower TDF value (9.2%) was reported for another BF preparation (Faisant et al., 1995). The TDF content in fibre-rich banana powder was higher (31.8%) than that in BF (Table 1), a change that relates to the liquefaction process, which solubilizes and eliminates a significant fraction of the fruit starch moiety (Table 1), thus concentrating the fibre portion. Compared to some antioxidant dietary fibres, TDF in the fibre-rich banana powder (31.8%) appears to be lower than that in guava (48–49%) (Jiménez-Escrig et al., 2001), grape skins (54.1–64.6%) (Bravo & Saura-Calixto, 1998; Saura-Calixto, 1998), citrus peel (57%) (Chau & Huang, 2003), fibre-enriched Mexican lime peels (66.7–70.4%) (Ubando et al., 2005) and mango peel (65–71%) (Larrauri et al., 1996) preparations. This relatively low TDF content in fibre-rich powder, prepared here, relates to its still high residual starch content (Table 1). Nonetheless, such a significant starch level might be useful in certain food products, given the additional functional properties imparted by starch.

The pulp of unripe banana features a high starch content (73.36%) (Juárez-García et al., 2006), (77.0%) (Faisant et al., 1995), and this was confirmed by the present results (76.8%, Table 1). In a previous work characterizing unripe BFs, TS contents between 61.3% and 76.5% were reported. The total starch (TS) content in the fibre-rich powder was lower (52.4%) than that in the unliquified banana flour (RBF), albeit still significant. Ungelatinized banana starch is not fully hydrolyzed by α-amylase. Such a phenomenon is often attributed to its particular granular structure (Faisant et al., 1995), for which a C-type X-ray diffraction pattern

was recently reported (Millan-Testa, Mendez-Montealvo, Ottenhof, Farhat, & Bello-Pérez, 2005). As will discussed later, the preparation of the fibre-rich powder implies a gelatinizing (boiling) step; hence, the high residual starch level suggests that the liquefaction conditions employed and not the granular resistance to digestion were responsible for the incomplete amylolysis. It should also be kept in mind that this high total starch content might contribute to the formation of other types of indigestible starch, such as retrograded resistant starch, during processing, of BF-based products, as has been shown in banana starch extrudates (González-Soto et al., 2006).

When resistant starch (RS) was evaluated in the banana flour, a high content was detected (30.4%), but the value decreased drastically in the fibre-rich powder (3.6%), a fact that confirms the effect of boiling during liquefaction of the sample, which destroyed the starch granular crystalline structure with the concomitant decrease in RS content (Table 1). Unripe banana is considered the RS-richest non-processed food. Faisant et al. (1995) determined high RS content in BF, reporting values between 47.3% and 57.2%, depending on the analytical method employed. TS and RS contents recorded here are in agreement with the potentially available starch (AS) level detected in both samples. AS in BF was 71.5%, reflecting that, during quantification of AS, the sample is boiled, a process that transforms native RS into AS. The fibre-rich powder, on the other hand, exhibited a lower AS content (48.5%) than that in its parental counterpart; this is due to the partial starch solubilization that takes place during the liquefaction phase of the method used for preparing the fibre-rich powder.

It has been reported that, additionally to non-digestible non-starch polysaccharides, total dietary fibre contain other polymeric substances that are unavailable for digestion in the small intestine; these move toward the colon where they may act as substrates for the fermentative microflora. This complex material was named indigestible fraction (IF) and it consists of soluble (SIF) and insoluble (IIF) fractions (Saura-Calixto et al., 2000). In the two samples studied, the IIF was higher than the SIF (Table 1), and the fibre-rich powder exhibited a significantly higher IIF value than its native counterpart. In this fraction (IIF), RS, indigestible protein, polyphenols and non-starch polysaccharides (cellulose, hemicellulose and lignin) are included. SIF (oligosaccharides and non-extractable polyphenols), however, was similar in both samples analyzed, suggesting no major difference in the indigestible monosaccharide, disaccharide and oligosaccharide composition. A similar pattern was reported in fruits, such as bananas, apples and oranges, where IIF is much higher than SIF (Saura-Calixto et al., 2000). Common beans and chickpeas also exhibit similar IIF and SIF patterns, but their total indigestible fraction values were lower (36.1% and 32.0%, respectively) than those recorded here for banana flour and banana fibre-rich powder (Menezes, De Melo, Lima, & Lajolo, 2004). The high total indigestible fraction present in the fibre-rich powder might be of use for the development of new products combining functional properties and low-calorie content.

3.2. Total soluble polyphenols

Extractable (or total soluble) polyphenol contents in banana flour and fibre-rich powder were similar, around 2 mg/g dry sample. This figure is lower than that in isolated mango dietary fibre (16.1 mg/g dry sample) but similar to that reported in apple fibre (3 mg/g dry sample) (Larrauri et al., 1996). In fruits, the average total polyphenol content was estimated to be 5.38 mg/g dry sample whereas, in vegetables, the estimation is 2.87 mg/g dry sample (Saura-Calixto & Goñi, 2006).

3.3. Antioxidant capacity

The antioxidant capacity of FRP, which is due to the total soluble polyphenol content, is shown in Fig. 1. The reducing effect of the fibre-rich preparation is fast, since the maximum value (90%) is sustained after 10 min of reaction. Using the same methodology, it was reported that

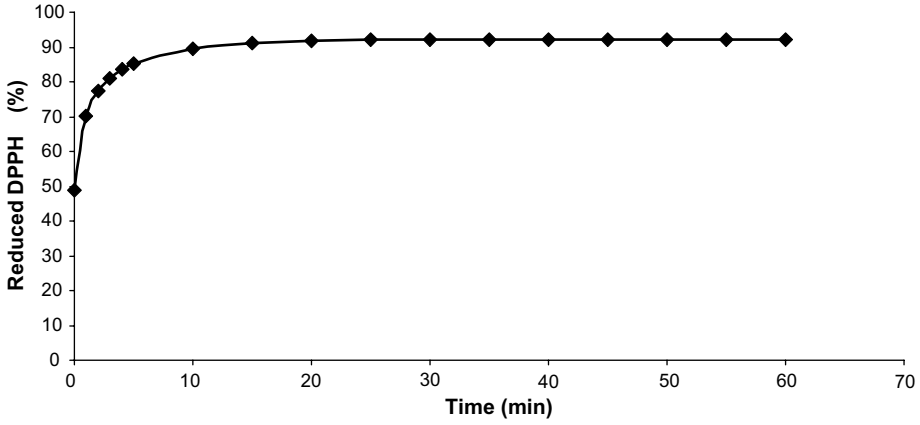

Fig. 1. Antioxidant activity in extract of fibre-rich powder obtained by liquefaction of banana flour.

white grain maize contains important concentrations of phenolic compounds, such as phenolic acid and flavonoids, with antioxidant capacity (Salinas-Moreno, Robles-Rodríguez, San Martín-Martínez, & Pérez-Herrera, 2006). The maximum reduction of phenolic compounds in those maize samples was 30% and a plateau was reached after 60 min. Hence, the phenolic compounds present in the banana fibre-rich powder have greater antioxidant capacity than has white maize, acting faster on free radicals.

3.4. Water- and oil-holding capacity

The results of water- (WHC) and oil-holding capacities (OHC) are presented in Fig. 2. The fibre-rich powder had higher WHC than had the native flour at 40 and 60 °C, and their behaviour was not affected by temperatures in this range. This may be related to the physical state of starch in each preparation. Starch granules present in the banana flour are not affected at those temperatures and have low water-holding capacity, whereas the preparation of fibre-rich powder may have released amylose, which has the capacity to effectively bind water molecules. When the measurement was performed at 80 °C, WHC of the fibre-rich powder did not change but the banana flour value increased more than 100% compared with that at 60 °C. This may be explained by the high total starch content in the native banana flour, that is gelatinized at 80 °C (Millan-Testa et al., 2005), that absorbs water into starch granules with concomitant swelling. The WHC value (2.5 g water/g dry sample) obtained in this study is lower than those reported in mango dietary fibre (12 and 15 g water/g dry sample at 40 and 60 °C, respectively) (Vergara-Valencia et al., 2007) and for mango peel dietary fibre (11 g/g) (Larrauri et al., 1996). Other WHC values reported

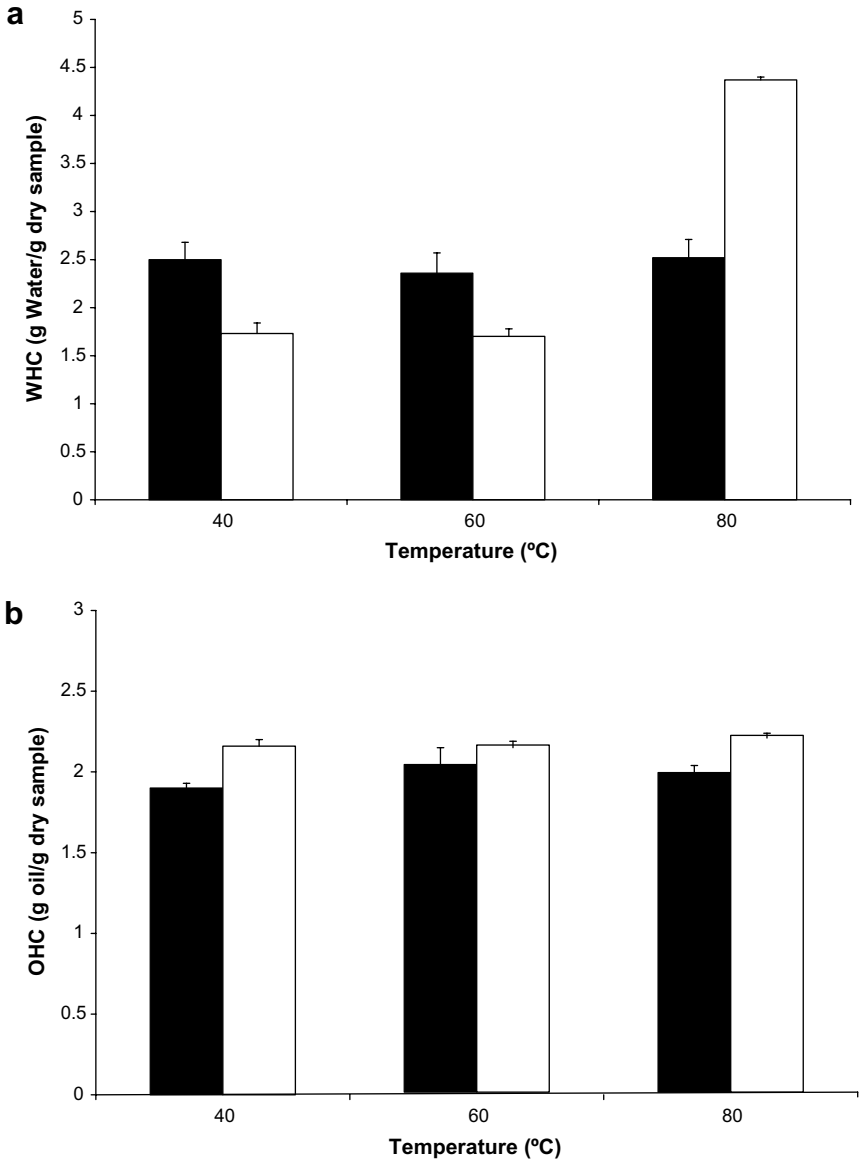

Fig. 2. Water-holding capacity (WHC) (a) and oil-holding capacity (WHC) (b) of fiber-rich powder, ■ and banana flour, □.

are in the range of 15.5–16.7 g of water/g citrus peel fibre (Chau & Huang, 2003) and between 6.96 and 12.84 g of water/g Mexican lime peel fibre (Ubando et al., 2005).

Another important functional property of fibre ingredients is the OHC which, in banana flour, was approximately 2.0 g of oil/g dry sample without statistical differences ($p \leqslant 0.05$) at the three temperatures assessed; the fibre-rich powder held 2.2 g of oil/g dry sample, regardless of the assay temperature. These values relate to the hydrophilic character of starch, which is abundant in both samples. Mango dietary fibre showed OHC values in a range between 1.0 and 1.5 g of oil/g, which may be considered low. Other fibre concentrates exhibit notably greater OHC, e.g. mango peel dietary fibre (approximately 4 g of oil/g (Larrauri et al., 1996) and citrus peel fibre (2.35–5.09 g of oil/g) (Chau & Huang, 2003). Accordingly, the use of banana fibre-rich powder may be appropriate in products where emulsifying properties are not required.

4. Conclusions

The chemical composition of fibre-rich powder prepared by liquefaction of raw banana flour (BFRP) indicates high total dietary fibre and indigestible fraction contents, intermediate total and available starch levels and low resistant starch content, valuable features for the preparation of certain types of food products. Its extractable polyphenol content was similar to that of apple fibre with very fast antioxidant capacity. Water- and oil-holding capacities of BFRP did not change with the temperature, an important characteristic during the processing of food products where this preparation may be added. Due to its high total dietary fibre and indigestible fraction contents the BFRP appears a promising ingredient for functional foods.

Acknowledgements

The authors acknowledge the economic support from SIP-IPN, COFAA-IPN, EDI-IPN, LANFOOD and CYTED (106PI0297).

References

American Association of Cereal Chemists. (2000). *Approved methods of the AACC. (2000)*. (10th ed.) The Association: St. Paul, MN.

Bravo, L., & Saura-Calixto, F. (1998). Characterization of dietary fibre and the in vitro indigestible fraction of grape pomace. *American Journal of Enology and Viticulture, 49*, 135–141.

Bello-Pérez, L. A., Sánchez-Hernández, L., Moreno-Damian, E., & Toro-Vázquez, J. F. (2002). Laboratory scale production of maltodextrins and glucose syrup from banana starch. *Acta Científica Venezolana, 53*, 44–48.

Chau, C. F., & Huang, Y. L. (2003). Comparison of the chemical composition and physicochemical properties of different fibre prepared from de peel of *Citrus sinensis* L. cv. Liucheng. *Journal of Agricultural and Food Chemistry, 51*, 2615–2618.

Da Mota, R. V., Lajolo, F. M., Ciacco, C., & Cordenunsi, B. R. (2000). Composition and functional properties of banana flour from different varieties. *Starch/Stärke, 52*, 63–68.

Faisant, N., Gallant, D. J., Bouchet, B., & Champ, M. (1995). Banana starch breakdown in the human small intestine studied by electron microscopy. *European Journal of Clinical Nutrition, 49*, 98–104.

Flores-Gorosquieta, E., García-Suárez, F. J., Flores-Huicochea, E., Núñez-Santiago, M. C., González-Soto, R. A., & Bello-Pérez, L. A. (2004). Rendimiento del proceso en la extracción de almidón a partir de frutos de plátano (*Musa paradisiaca*) Estudio en planta piloto. *Acta Científica Venezolana, 55*, 86–90.

Frankel, E. N., & German, J. B. (2006). Perspective: Antioxidants in foods and health: Problems and fallacies in the field. *Journal of the Science of Food and Agriculture, 86*, 1999–2001.

González-Soto, R. A., Sánchez-Hernández, L., Solorza-Feria, J., Nuñez-Santiago, C., Flores-Huicochea, E., & Bello-Pérez, L. A. (2006). Resistant starch production from non-conventional starch sources by extrusion. *Food Science and Technology International, 12*, 5–11.

Goñi, I., García-Díaz, L., Mañas, E., & Saura-Calixto, F. (1996). Analysis of resistant starch. A method for food products. *Food Chemistry, 56*, 445–449.

Goñi, I., García-Alonso, A., & Saura-Calixto, F. (1997). A starch hydrolysis procedure to estimate glycemic index. *Nutrition Research, 17*, 427–437.

Holm, J., Bjorck, I., Drew, A., & Asp, N. G. (1986). A rapid method for the analysis of starch. *Starch/Stärke, 38*, 224–229.

Jiménez-Escrig, A., Jiménez-Jiménez, I., Pulido, R., & Saura-Calixto, F. (2001). Antioxidant activity of fresh and processed edible seaweeds. *Journal of Science and Food Agriculture, 81*, 530–534.

Juárez-García, E., Agama-Acevedo, E., Sáyago-Ayerdi, S. G., Rodríguez-Ambriz, S. L., & Bello-Pérez, L. A. (2006). Composition, digestibility and application in breamaking of banana Fluor. *Plant Foods for Human Nutrition, 61*, 131–137.

Larrauri, J. A., Rupérez, P., Borroto, B., & Saura-Calixto, F. (1996). Mango peels as a new tropical fibre: Preparation and characterization. *Lebensmittel-Wissenschaft und Technologie, 29*, 729–733.

Machado-Rocha, S., de Queiroz, J., Lopes-Ribeiro, M., Milagres-Campos, F., & Pinheiro-Santana, H. (2007). Antioxidant in mango (*Mangifera indica* L.) pulp. *Plant Foods for Human Nutrition, 62*, 13–17.

Menezes, E., De Melo, A., Lima, G., & Lajolo, F. (2004). Measurement of carbohydrate components and their impact on energy value of foods. *Journal of Food Composition and Analysis, 17*, 331–338.

Millan-Testa, C. E., Mendez-Montealvo, M. G., Ottenhof, M. A., Farhat, I. A., & Bello-Pérez, L. A. (2005). Determination of the molecular and structural characteristics of okenia, mango and banana starches. *Journal of Agricultural and Food Chemistry, 53*, 495–501.

Official Methods of Analysis. (1999). *Association of official analytical chemists*. (16th ed.) Washington, DC, EUA.

Salinas, M. Y., Soto, H. M., Martinez, B. F., Gonzalez, H. V. y., & Ortega, P. R. (1999). Analisis de antocianinas en maices de grano azul y rojo provenientes de 4 razas. *Revista Fitotecnia Mexicana, 22*, 161–174.

Salinas-Moreno, Y., Robles-Rodríguez, R. R., San Martín-Martínez, E., & Pérez-Herrera, P. (2006). *Antioxidant activity in masa and tortilla from pigmented maize grains. Memories of 4th international congress on pigments in foods*. Berlin: Springer (pp. 131–133).

Saura-Calixto, F. (1998). Antioxidant dietary fibre product: A new concept and a potential food ingredient. *Journal of Agricultural and Food Chemistry, 48*, 4303–4306.

Saura-Calixto, F., García-Alonso, A., Goñi, I., & Bravo, L. (2000). In vitro determination of the indigestible fraction in foods: An alternative to dietary fibre analysis. *Journal of Agricultural and Food Chemistry, 48*, 3342–3344.

Saura-Calixto, F., & Goñi, I. (2006). Antioxidant capacity of the Spanish Mediterranean diet. *Food Chemistry, 94*, 442–447.

Soler-Rivas, C., Espin, J. C., & Wichers, J. H. (2000). An easy and fast test to compare total free radical scavenger capacity of foodstuffs. *Phytochemical Analysis, 11*, 330–338.

Ubando, J., Navarro, A., & Valdivia, M. A. (2005). Mexican lime peel: Comparative study on contents of dietary fibre and associated antioxidant activity. *Food Chemistry, 89*, 57–61.

Vergara-Valencia, N., Granados-Pereza, E., Agama-Acevedo, E., Tovar, J., Ruales, J., & Bello-Pérez, L. A. (2007). Fibre concentrate from mango fruit: Characterization, associated antioxidant capacity and application as a bakery product ingredient. *Lebensmittel-Wissenschaft und Technologie, 40*, 722–729.