Zagazig J. Agric. Res., Vol. 49 No. (6) 2022 841-852

Biotechnology Research

Available online at http://zjar.journals.ekb.eg
http:/www.journals.zu.edu.eg/journalDisplay.aspx?Journalld=1&queryType=Master

CHEMICAL AND FUNCTIONAL PROPERTIES OF THE NATIVE BANANA (MUSA) PSEUDO-STEM

Amany H.T. Hefnawy*, A.E. Awad, K.M. Wahdan and M.A. Doheim

Agric. Bioch. Dept., Fac. Agric., Zagazig Univ., Egypt

Received: 09/08/2022 ; Accepted: 11/11/2022

ABSTRACT: This research was conducted to evaluate the differences in chemical composition and functional properties of native banana pseudo-stem flour (T_1) and tender core of the banana pseudo-stem flour (T_2). Chemical analyses indicated that the proximate contents (moisture, fat, protein and ash), were higher in (T_2) than in (T_1). The levels of total dietary fiber, insoluble dietary fiber, lignin, hemicellulose and cellulose were all higher in (T_1) than (T_2), while there was no difference in soluble dietary fiber. (T_1) also had higher contents of polyphenols and flavonoids than (T_2). Also, antioxidant capacity and free radical-scavenging capacity were higher in (T_1) than in (T_2). On the other hand, the (T_2) showed higher swelling power, water holding capacity and solubility, although its oil holding capacity was lower than (T_1). Results conclude that banana pseudo-stem flour is a potential functional food ingredient for products containing high dietary fiber. Phytochemical screening was done on water extract and ethanol extract. Also phytochemical tests indicate the presence of phenolic compounds: Flavonoids, Alkaloids, Tannins, Saponins, Steroids, and Glycosides.

Key words: Banana pseudo-stem, dietary fiber, lignin, cellulose, hemicellulose, phenolic compounds.

INTRODUCTION

Bananas (Musa spp.) are one of the most important fruits in the world and the fourth most important food crop after rice, wheat, and corn. Banana is an excellent source of starch that is accepted as a staple or supplement diet worldwide including Asia, Africa, and Central and South America. Palatability, cheaper source of instant energy, and richness in macronutrients are some of the characteristics which have paved the way for banana high acceptance by consumers (**Deng *et al.,* 2020**). Besides the use of banana as food or supplemental food, the whole plant has potential commercial use in different industries such as packaging and pharmaceutical (**Ponnuswamy** *et al.,* 2011). Although banana fruit has been the focus of interest for scientists to increase its value with biofortification (**Borges *et al.,* 2014**) and yield (**Ganeshamurthy** *et al.,* 2011), less attention was given to other plant parts, including pseudo-stem and leaves.

Apart from the fruits, the inforescence, pseudo-stem, rhizome and leaves of banana are also consumed locally and traditionally in several regions (**Borborah *et al.,* 2016**). Nearly 1 million hectares of land is under banana cultivation, which is in addition to the plants growing in wild condition (**Pareek, 2016**). A huge amount of agricultural waste is thus generated every year after the harvesting of fruits in the form of pseudo-stems and leaves. Therefore, the viable utilization of these agro residues is of utmost importance to reduce wastage.

The banana pseudo-stem is particularly rich in cellulose, hemicellulose, protein, fat and dietary fbres along with other nutritive elements (**Rochana *et al.,* 2017**). The presence of polyphenols and favonoids, viz. ferulic acid, cinnamic acid, catechin, gingerol, with promising antioxidative activities has been reported (**Saravanan and Aradhya, 2011**). It was shown that the methanolic extract of the pseudo-stem

*** Corresponding author: Tel. :**+201110051873
E-mail address: amany98@gmail.com

possesses signifcant hypolipidemic and antihypercholesterolemic properties (**Dikshit *et al.*, 2016**). Banana pseudo-stems also exhibited antimicrobial properties against both gram-positive and gram-negative bacteria and even antitumor activity against hepatocellular carcinoma (HepG-2) and human colon carcinoma (HCT-116) cell lines (**Abdel Ghany *et al.*, 2019)**. Therefore, consumption of banana pseudo-stem can be benefcial, and hence, materializing its usage in food products appears noteworthy. In this connection, some attempts have been undertaken in the past. **Sharma *et al.* (2017**) reported the preparation of a functional juice from pseudo-stem with prebiotic properties containing glucooligosaccharides and D-allulose. carboxymethylcellulose obtained from banana pseudo-stem was reported to be used as a natural thickening and gelling agent in food items (**Padam *et al.*, 2014**). Apart from that, the fermentation of banana pseudo-stem

The stem of the banana plant, which is also called pseudo-stem produces a single bunch of bananas before dying and is replaced by a new pseudo-stem (**Anhwange *et al.*, 2009**). This crop generates a large amount of residue, due to the fact that each plant produces only one bunch of bananas. After the harvest, the bare pseudo-stem is cut and usually left on the plantation or burned, which could ultimately cause environment issues (**Cordeiro *et al.*, 2004**). Thus, the utilization of the banana waste pseudo-stems has gained more attention in recent years. The banana pseudo-stem has been used as material for paper, furniture and forage (**Buragohain *et al.*, 2010**).

Moreover, it has been reported that banana waste materials are rich in minerals and nutrients, especially dietary fibre (**Aziz *et al.*, 2011).** The exploitation of waste banana pseudo-stems into products could significantly benefit the environment and increase its economic value. The banana pseudo-stem could potentially be used more in food rather than in other industries (**Tiroutchelvame *et al.*, 2019)**. Pseudo-stem have low glycemic index and have a high content of dietary fibre and antioxidant which is good for diabetes (**Bhaskar *et al.*, 2011**).

Several studies have been carried out to determine the chemical and functional properties of banana flour, banana starches and fiber-rich powder from unripe banana flour (**Rodriguez *et al.*, 2008**).

Crude extracts of plant materials rich in phenolic compounds are of increasing interest in the food industry because they retard oxidative degradation of lipids and thereby improve the quality and nutritional value of food. The importance of the antioxidant constituents of plant materials in the maintenance of health, and in protection from coronary heart disease and cancer, have resulted in an increased interest among scientists, food manufacturers, and consumers. The trend of the future is moving towards functional foods with specific health effects (**Kallay and Kerenyi, 1999**). The objective of this investigation is to study the chemical composition and functional properties of processed native banana pseudo-stem.

MATERIALS AND METHODS

Materials

Fresh banana (*Musa*) pseudo-stem was collected from a local banana farm in (A farm in New Salhiya-Al Sharqiya). The banana pseudo-stem and the tender core of the pseudo-stem flour were then processed as described below (Fig. 1). The outer sheath of the banana pseudo-stem was peeled off to obtain the inner central core (diameter < 6 cm), which was then cut into small pieces, and dried in a hot air oven at 50°C for 48 h (Fig. 1). After drying, the plant sample was milled using a mechanical grinder and sieved through 0.2-mm sieve to obtain a fine powder (Fig. 1). The powder was finally stored in an airtight container at 4°C for further use.

Flour Processing

Native banana pseudo-stem flour (T_1) was processed by peeling off the epidermis (skin) of the stem manually with a sterile knife. Furthermore, to process the (T_2), several layers of stem cells were peeled off to reach the central 4–5 cm core of the pith. The peeled pseudo-stem and the tender core were rinsed with running tap water and cut into small pieces. The tender core was then boiled for 15 min. to remove the mucus content of the inner stem. Both samples were then sliced using a mechanical slicer (Robot Coupe, France) before being dried in a

Fig. 1. a. Banana pseudo-stems, b. Pseudo-stems chopped into small pieces for drying, c. Dried pseudo-stem for milling, d. Pseudo-stem four (BPF) sample

ventilated dryer (Afos, Model Mini, No. CK 80520, England) at 60 C for 24 h. The dried slices of both the pseudo-stem and tender core were then ground in a blender and further sieved through a 355-lm mesh sieve. (T1) and (T2) were then kept in airtight plastic containers and stored in a refrigerator at 4°C prior to use.

Proximate Analysis

Moisture, ash, crude fat, crude fiber, crude protein and carbohydrate contents of (T1) were determined according to the **AACC Method (2000**).

The carbohydrate fractions were estimated from (total soluble sugars, reducing sugars, total sugars and soluble non-reducing sugars). This is done by the difference between total soluble sugars and reduced soluble sugars according to the method of 3,5-dinitrosalicylic acid (**Miller, 1959**).

Mineral Analysis

(T1) and (T2) were assessed for comprehensive mineral analysis (K, Ca, Zn, Li and Mo) were determined using flame atomic absorption spectroscopy (AAS, Varian 240, USA) Aliquots of a solution comprising 69% HNO_3 (6 mL) and 30% H_2O_2 (1 mL) were added to a 1 g dried ground banana pseudo-stem sample. The digested samples were then transferred into a 100 mL volumetric flask and made up to the volume (**Ho *et al.*, 2012**). The results were expressed in milligrams per 100 g dry sample.

Total Dietary Fiber Determination

Total dietary fiber content and fraction of fiber were determined according to **AOAC (2010)**.

Color Analysis

Colorimeter (MINOLTA, CR-300, Japan) was used to determine the colour of the banana pseudo-stem samples. L* values, a* values and b* values were detected as the indication of whiteness (**Ho *et al.*, 2017**)

Determination of Lignin, Cellulose and Hemicellulose Content

Acid detergent fiber (ADF) and lignin, as well as neutral detergent fiber (NDF), were measured according to method 973.18 and method 2002.04, respectively (**AOAC, 2010**).

Determination of Total Phenolic Compounds

Total phenolic content of the (T1) and TCBPC were determined using a Folin–Ciocalteu (FC) assay based on the method described by **Alothman *et al.* (2009**), with some modifications. In brief, freeze–dried extracts (1

mg) of (T1) and (T2) were dissolved in 4 ml of methanol. Furthermore, 400 ll of the resulting solution were mixed with 2 ml of FC phenol reagent. The reagent was pre-diluted, 10 times, with distilled water. After standing for 5 min at room temperature, 1.6 ml of (7.5% w/v) sodium carbonate solution was added. The solutions were mixed and allowed to stand for 1 h at room temperature. The absorbance was measured at 765 nm, using a UV–visible spectrophotometer (Shimadzu UV1601PC, Japan). A calibration curve was prepared, using a standard solution of gallic acid. Results were expressed as milligrams of gallic acid equivalents per hundred grams of freeze–dried extract (mg GAE/ 100 g of dry weight).

Total Flavonoid Assay

Total flavonoid content was measured by the aluminium chloride colorimetric assay (**Alothman *et al.*, 2009**). One ml of properly diluted freeze dried extract of (T1) and (T2) was mixed with 4 ml of distilled water. Initially 0.3 ml of (5% w/v) $NaNO_2$ was added. After 5 min, 0.3 ml of (10% w/v) $AlCl_3$ was added. At 6 min, 2 ml of 1 M solution of NaOH were added. After that, the volume was made up to 10 ml, immediately, by the addition of 2.4 ml of distilled water. The mixture was shaken vigorously and the absorbance of the mixture was read at 510 nm. A suitable calibration curve was prepared using a standard solution of catechin and the results were also expressed on a dry weight basis as mg catechin equivalents (CEQ)/100 g of sample.

Antioxidant Properties

Phytochemical screening test

Test for Flavonoids: To 1-ml of the extract was added 3 drops of ammonia solution (NH_3^+) followed by 0.5ml of concentrated HCl. The resultant pale brown colouration of the entire mixture indicated the presence of flavonoids (**Taher *et al.*, 2018**).

Test for Alkaloides: To 3ml of the extract was added 1ml of 1% HCl. This resulting mixture was then treated with few drops of Meyer's reagent. The appearance of a creamy white precipitate confirmed the presence of alkaloids (**Prieto *et al.*, 1999).**

Test for Tannins: Two drops of 5% $FeCl_3$ was added to 1ml of the plant extract. The appearance of a dirty-green precipitate indicated the presence of tannins (**Vilela *et al.*, 2014**).

Test for Saponins: Five drops of olive oil was added to 2ml of the plant extract and the mixture shaken vigorously. The formation of a stable emulsion indicated the presence of saponins (**Vilela *et al.*, 2014**).

Test for Steroids: To 1ml of the plant extract was added 1ml of concentrated tetraoxosulphate (vi) acid (H_2SO_4). A red colouration confirmed the presence of steroids (**Vilela *et al.*, 2014**).

Test for Glycosides: To 1ml of the extract was added 2ml of acetic acid and then cooled in an ice bath at 4°C. To this mixture 1ml of concentrated tetraoxosulphate (vi) acid (H_2SO_4) was added dropwise. The formation of an oil layer on top of solution indicated the presence of glycosides

Preparation of flour extract

(T1) samples were extracted using methanol, [1:10 (w/v)] at room temperature for 24 h in an orbital shaker at 170 rpm. Supernatants were filtered through Whatman No. 1 filter paper, and the filtrate was then collected. The extracts were concentrated using a rotary evaporator under reduced pressure at 40°C for 5 h. The concentrated solutions were freeze–dried and stored at 20°C for further use.

DPPH free radical-scavenging assay

The determination of DPPH free radical-scavenging by (T1) and (T2) were based on the method proposed by **Mosquera *et al.* (2007),** with sight modifications. Freeze–dried extracts (1 mg) of (T1) and (T2) were dissolved in 4 ml of methanol. Afterwards, 0.1 ml of the resulting solution was mixed with 3.9 ml of DPPH solution (0.025 g/l methanol). The mixture was incubated at room temperature for 30 min. The DPPH solution without extracts was prepared as a control. The absorbance was measured at 517 nm using a spectrophotometer and against a blank of methanol without DPPH. Results were expressed as milligrams of trolox equivalents per hundred grams of freeze–dried extract (mg TEAC/100 g dry weight).

Determination of swelling power, solubility profiles, and water and oil holding capacities

Swelling power and solubility were measured using the method of **Adebowale *et al.* (2002),** with slight modifications. (T1) and (T2) (0.5 g) were accurately weighed into previously tared 50 ml dry centrifuge tubes. Next, 20 ml of distilled water was pipetted into the centrifuge tubes containing the samples. The suspensions were then stirred with a magnetic stir bar for 30 min at room temperature and centrifuged (3500 rpm, 30 min). The residues obtained after centrifugation were weighed as swollen granules (g of swollen granules per g of dry sample). Meanwhile, aliquots of the supernatants were dried to a constant weight at 110°C. The residue obtained represented the amount of flour granules solubilised in water (g of dry weight at 110°C per g of dry sample).

The water holding and oil holding capacities were determined based on the standard methods (**Traynham *et al.*, 2007**). First, 25 ml of distilled water (for water holding capacity, WHC) or commercial olive oil (for oil holding capacity, OHC) was added to 250 mg of dry flour samples, stirred with a magnetic stir bar for 30 min and left at room temperature for 30 min. After centrifugation at 3500 rpm for 30 min, the supernatants were decanted, each centrifuge tube was weighed then the WHC and OHC was calculated as g water or oil per g of dry sample, respectively.

RESULTS AND DISCUSSION

Proximate Analysis

Results in Table 1 indicated that the proximate compositions of the two samples were with the exception of carbohydrate content. (T2) had a content of moisture, fat, protein, and ash (8.82%, 1.18%, 3.52% and 10.08%, respectively), than (T1), but a lower level of crude fibre (19.51%). However, by comparison, the moisture content of both (T1) and (T2) were lower than commercial wheat flour. The moisture of the dried product has a critical influence on storage stability. In addition, textural quality, chemical and biochemical reactions, as well as microbial growth rates are greatly affected by the moisture content of food products (**Ovando *et al.*, 2009**). The fat contents of (T1) and (T2) were found to be 0.24% and 1.18%, respectively. These values were lower than those reported by others for banana flour prepared from the whole fruit (pulp and peel) of unripe banana, which had a fat content of 2.7% (**Juarez *et al.*, 2006**). Others report fat content varying from 2.2% to 10.9% at different stages of ripeness in banana and plantain peels (**Happi *et al.*, 2007**). Based on the results, it was evident that the fat composition of (T1) and (T2) is lower than the pulp and peel of the banana. Protein content of (T1) and (T2) was also lower (0.89% and 4.52%, respectively), compared to wheat flour (13.31%) as reported by **Traynham *et al.* (2007).** The higher protein content in (T2) compared with (T1) may be attributed to the boiling step applied during the processing of (T2), which dissolves certain water-soluble proteins (**Rodriguez *et al.*, 2008**).

Ash content determination indicated that (T2) (10.08%) contained significantly higher mineral levels than (T1) (3.03%). The ash content in (T1) and (T2) (3.03–10.8% dry matter) was composed of high levels of potassium and zinc (**Happi *et al.*, 2007**). (T1) and (T2) were composed of 29.92% and 19.51% crude fiber, respectively. The lower content of crude fiber in (T2) compared with (T1) might be attributed to the solubilisation of polysaccharides during the thermal treatment on processing (T2), which results in a decrease of the content of total fiber (**Tatjana *et al.*, 2002**).

Minerals

Based on the amount required for the human body, minerals are classified as macro- and micro-elements. The minerals present in (T1) and (T2) are given in Table 2 which suggests the presence of K and Zn being the major mineral in both (T1) and (T2). However, minerals in (T2) were about 2–5-fold higher than the levels in (T1). The levels of minerals in (T2) were in the order Zn > K while that of (T1) was in the order Zn > K. While K was involved in the ion pumps in several metabolic pathways and Ca along with P forms Ca_3 $(PO_4)_2$ and are essential for bone and teeth formation (**Joseph *et al.*, 2013**). Overall, the levels of these minerals were in agreement with that of *Musa* spp. *Baxijiao* and *Paradisiacal* flower variety, but slightly lower than the limiting contents found in banana peels and pulps determined by **Shaida *et al.* (2011)**.

Table 1. Proximate composition and carbohydrates fraction of (T1) and (T2)

Composition (%)	(T1)	(T2)
Moisture	8.34	8.82
Fat	0.24	1.18
Protein	0.89	3.52
Ash	3.03	10.08
Crude fibre	29.92	19.51
Total carbohydrate	57.58	56.89
Reducing soluble carbohydrates	6.68	4.52
Non-reducing carbohydrates	49.95	51.64

T_1: Native banana pseudo-stem flour ; T_2: tender core of the banana pseudo-stem flour

Table 2. Mineral composition of (T1) and (T2) (ppm)

Elements	(T2)	(T1)
Potassium (K)	10.63	51.29
Calcium (Ca)	4.01	10.65
Zinc (Zn)	16.60	207.90
Lithium (Li)	0.012	0.034
Molybdenum (Mo)	0.028	0.042

T_1: Native banana pseudo-stem flour ; T_2: tender core of the banana pseudo-stem flour

Microelements also have several vital biological functions. Zn is involved in various reactions of the body to construct and maintain DNA, required for the growth and repair of body tissues and iron along with manganese, copper, and zinc are constituents of various important proteins and enzymes involved in macro-nutrient metabolism and body function. Considering the several vital functions of the macro- and micro-elements, their high contents in (T2) and (T1) could contribute to explain their use in folk medicine.

Cellulose, Hemicellulose and Lignin Contents

The chemical composition of the banana pseudo-stem and its tender core are shown in Table 3. Cellulose, hemicellulose and lignin are components of plant fibers that are classified as insoluble.

Among these, lignin is resistant to digestion. Within the dietary fiber fraction, cellulose was the most abundant component, followed by hemicellulose and then lignin in both (T1) and (T2) (42.09%, 18.56%, 5.13% and 27.42%, 11.87%, 4.60%, respectively). Thus, banana pseudo-stem has higher amounts of cellulose than both (T1) (7.5–9.6%) and (T2) (6.4–7.8%) at various stages of maturation (**Happi *et al.*, 2008**). The high content of cellulose in banana pseudo-stem can be explained by the fact that cellulose is the main substance that forms the primary and secondary walls of plant cells. The cellulose content of (T1) reported in this study is similar to the cellulose content in the outer bark material of pseudo-stems of *M. acuminata* Colla (40.2%), as reported by **Cordeiro *et al.* (2004**).

The high content of cellulose in (T1) may also correspond to the high acid detergent fiber content (47.22%). Interestingly, **Rose *et al.* (2010)** reported that the major constituent of corn

Table. 3 Cellulose, hemicellulose and lignin content in (T1) and TCBP

Composition (%)	(T1)	(T2)
Cellulose	42.09	27.42
Hemicellulose	18.56	11.87
Lignin	5.13	4.60
Total dietary fibre	67.07	47.98

T_1: Native banana pseudo-stem flour ; T_2: tender core of the banana pseudo-stem flour

bran fiber was hemicellulose (70%), followed by cellulose (28%), whereas the results from our present study showed the reverse. Both (T1) and (T2) have higher lignin content than wheat and soy meal, which contain only 0.88% and 0.58% lignin, respectively, as reported by **Moller (2009)**. On the other hand, lignin levels are considerably lower in (T1) and (T2) as compared with other wood-based materials such as sawdust (20.33%). In addition, both (T1) and (T2) contained less lignin than banana (pulp) (6.0–12.1%) and plantain (green banana) (14.3– 16.8%) (**Happi *et al.*, 2008**). Moreover, **Mukhopadhyay *et al.* (2008)** have reported the lignin content in banana pseudo-stem fibers of *Musa sapientum* species (15.07%) to be much higher than the results obtained in our present study. Unlike lignin, the higher hemicellulose content in (T1) corresponded with the higher content of neutral detergent fiber (65.78%). The relative amounts of hemicellulose and cellulose in our study are in accordance with those published by **Mukhopadhyay *et al.* (2008)**, who also reported lower hemicellulose content as compared to cellulose in banana pseudo-stem. However, the fiber data obtained in the present study are different from those reported by **Mukhopadhyay *et al.* (2008**) (14.98% hemicellulose and 31.27% cellulose). This discrepancy may be due to the differences in the banana species used in these two studies. The TDF content of (T1) and (T2) (67.07% and 47.98%, respectively), indicated that (T1) contained higher levels of fibre than (T2).

Phytochemical Screening Result

Phytochemicals are known to occur in various parts of plants with diverse functions which include provision of strength to plants, attraction of insects for pollination and feeding, defence against predators, provision of colour, while some are simply waste products (**Ibegbulem *et al.*, 2003**). When ingested by animals these secondary metabolites exhibit varied biochemical and pharmacological actions (**Amadi *et al.*, 2006**). The phytochemical test revealed that the extract of banana pseudo-stem liquid showed flavonoids, alkaloids, tannins, saponins, steroids and glycoside. And from Table 4, it was observed that the most abundant content in the aqueous and ethanol extract. The presence of virtually all the phytochemicals in the water extract connotes that water could be used as the main solvent for the extraction of the metabolites for pharmaceutical purposes. The presence of these phytochemicals in the banana pseudo stem confers medicinal properties on the plant and this explains the use of this plant for treatment of different ailments. The findings of this study are consistent with reports of the presence of these phytochemicals in various parts of the banana plant as documented by (**Akpuaka and Ezem, 2011**).

Antioxidant Properties

The total phenolic content in the methanolic extracts of (T1) and (T2), is shown in Table 5. The phenolic content of (T1) (6532 mg GAE/ 100 g of dry weight) was significantly higher than the phenolic content of (T2) (1245 mg GAE/100 g of dry weight). This difference might be attributed to the fact that the outer layers of the banana pseudo-stem have greater concentrations of phenolic compounds than the pith. We conclude that phenolic compounds are more abundant in banana pseudo-stem than in the pulp and peel (232 mg/100 g weight and 907 mg/100 g dry weight, respectively) (**Someya *et al.*, 2002**). However, further studies are warranted to identify individual phenolic compounds present in (T1) and (T2), which might provide more details. With regard to the total flavonoid

Table 4. Phytochemical screening Test Results of Water Extract and Ethanol Extract of Banana pseudo-stem

Phytochemical constituent	(T_1)		(T_2)	
	Water Extract	Ethanol Extract	Water Extract	Ethanol Extract
Flavonoids	++	++	+	+
Alkaloids	+	-	+	+
Tanins	+	-	+	+
Saponins	+	-	+	+
Steroids	++	+	-	+
Glycosides	+	++	+	-

Note: (-) absent, (+) present in low concentration and (++) present in high concentration

T_1: Native banana pseudo-stem flour ; T_2: tender core of the banana pseudo-stem flour

Table 5. Total phenolic content and antioxidant activity in (T1) and (T2)

Compounds	(T1)	(T2)
Total phenolics (mg GAE/100 g of dry weight)	6532	1245
Total flavonoids (mg CEQ/100 g of dry weight)	4500	1042
DPPH value (mg TEAC/100 g of dry weight)	2422	842

T_1: Native banana pseudo-stem flour ; T_2: tender core of the banana pseudo-stem flour

content, (T1) had a higher total flavonoids (4500 mg CEQ/100 g of dry weight) than the (T2) (1042 mg CEQ/100 g of dry weight) (Table 4). The correlations performed between total phenolics and total flavonoid assays showed it to be 0.901 and 0.929 for (T_1) and (T_2), respectively. In general, phenolic compounds are widely distributed in the plant kingdom and they have been reported to possess strong antioxidant properties (**Mosquera *et al.*, 2007**). The antioxidant activity of banana pseudo-stem flours is expressed as mg TEAC/100 g, and inhibition of DPPH radicals corresponds to the antioxidant activity.

Swelling Power, Solubility Profiles, and Water and Oil Holding Capacity

Swelling power, solubility, water and oil holding capacities of (T1) and TCPBF are presented in Fig. 2. The (T_2) swelling power (13.82 g swollen granules/g of dry matter) exceeded that of (T1) (9.48 g of swollen granules/g of dry matter). This result was due to the boiling (100°C) process applied in preparation of the banana tender core flour. According to **Bello-Perez *et al.* (1999)**, high temperatures lead to the solubilisation of amylase during starch gelatinisation. It is also possible that the high swelling power is due to a high amylopectin content; the latter possibility could be explored using structural studies. The extent of water retained in the swollen granules of (T_2) was greater than (T_1) and paralleled a higher percent solubility of (T_2) (33.28%) vs. (T_1)(3.44%). Both WHC and OHC are important functional properties that have been widely studied in food, as they are associated with food quality. (T_1) and (T_2) had WHCs of 10.66 and 18.28 g of water/g of dry matter, respectively. These values far exceed those from the dietary fibers of oat bran, rice bran, soy flour and wheat bran, namely 2.10, 4.89, 4.79–6.75, and 5.03 g of water/g of dry matter, respectively (**Heywood *et al.*, 2002**). Thus, (T_1) and (T_2) are able to bind or entrap more water than oat bran, rice bran and soy flour. In contrast, (T_1) has a WHC value on par with apple fiber (9.36 g of water/ g of dry matter)

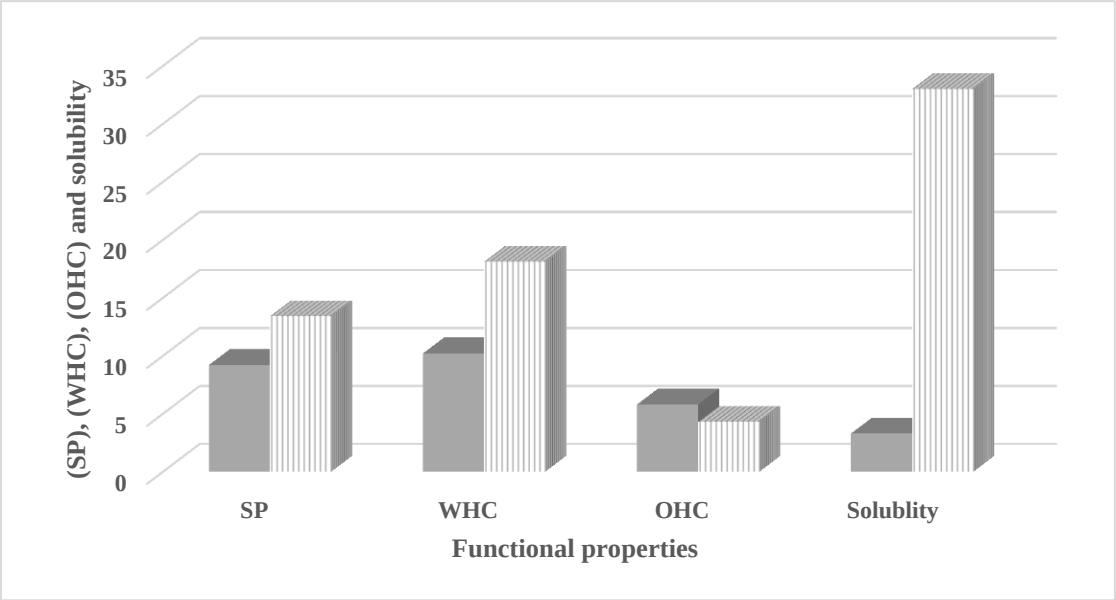

Fig. 2. Swelling power (SP), water holding capacity (WHC), oil holding capacity (OHC) and solubility of (T_1) and (T_2)

as reported by **Chen *et al.* (1988).** This small difference may be due to the structural differences in cell wall components between the stem and fruit fibers (**Chen *et al.*, 1988**). The lower WHC value of (T_1) as compared with (T_2) may be due to boiling (T_2) during processing. Starch granules present in (T_1) are not affected at high temperatures and have a low WHC, whereas the preparation of (T_2) may have released amylose, which effectively binds water molecules (**Rodriguez *et al.*, 2008**). Another important functional property of the fiber ingredients is the OHC which, in (T_1) and (T_2), was 5.48 and 3.88 g of oil/g of dry matter, respectively. The results showed that (T_1) and (T_2) have higher OHC values than dietary fiber obtained from commercial preparations (1.29 g of oil/g of dry matter) as reported earlier by **Abdul and Luan (2000**). The differences in OHC between (T_1) and (T_2) might be attributed to their differences in chemical and physical structure, as well as their differences in preparation. (T_1) may be potentially suitable for use in food products as an aid in stabilising emulsions and as a rich source of dietary fiber.

Conclusions

Native banana pseudo-stem flour (T_1) has a higher amount of fibre (crude fibre, insoluble dietary fibre, total dietary fibre, cellulose, hemicellulose and lignin) than (T_2). The phenol content, flavonoid content, antioxidant capacity and free radical-scavenging capacity were all higher in (T_1) than in (T_2). Boiling process increased the (T_2) functional profile in terms of swelling power, water holding capacity and solubility. Results from this research clearly showed that the high fiber, WHC and OHC of (T_1) and (T_2) are potentially suitable for use in food applications as a new low-calorie, high-fiber ingredient. From the initial phytochemical test, Musa paradisiaca Linn stem fluid contained flavonoids, alkaloids, tannins, saponins, steroids and glycoside. The highest content is in the liquid fraction.

REFERENCES

AACC (2010). American Association of Cereal Chemists Approved Methods (19th Ed.). MN: St. Paul.

Abdel Ghany, T.M., M. Ganash, M.M. Alawlaqi and A.M.H. Al-Rajhi (2019). Antoixidant, antitumor, antimicrobial activities evaluation of *Musa paradisiaca* L. pseudo-stem exudate cultivated in Saudi Arabia. Bio. Nano. Sci., 9: 172–178.

Abdul, H.A. and S.Y. Luan (2000). Functional properties of dietary fiber prepared from defatted rice bran. Food Chem., 68: 15–19.

Adebowale, K.O., T. Adeniyi Afolabi and O.S. Lawal (2002). Isolation, chemical modification and physicochemical of *Bambarra groundnut* (*Voandzeia subterranean*) starch and flour. Food Chem., 78: 305–311.

Akpuaka, M.U. and S.N. Ezem (2011). Preliminary photochemical screening of some *Nigerian dermatological* plants. J. Basic. Phys. Res., 2 (1): 1-5.

Alothman, M., R. Bhat and A.A. Karim (2009). Antioxidant capacity and phenolic content of selected tropical fruits from Malaysia, extracted with different solvents. Food Chem., 115: 785–788.

Amadi, B.A., C.O. Ibegbulem and A.C. Egbebu (2006). Assessment of the effect of aqueous extract of *Asimina triloba* root on organ weights and liver function of albino rats. Int. J. Natural and Appl. Sci., 2 : 79-81.

Anhwange, B.A. (2008). Chemical Composition of *Musa sapientum* (Banana) Peels, J. Food Technol., 6 (6): 263–266.

AOAC (2010). Official Methods of Analysis of AOAC Int. (23^{th} Ed.). Washington, DC.

Aziz, N.A.A., L.H. Ho, B. Azahari, R. Bhat, L.H. Cheng and M.N.M. Ibrahim (2011), Chemical and functional properties of the native banana (*Musaacuminata balbisiana*) pseudo-stem and pseudo-stem tender core flours. Food Chem., 128: 748-753.

Bello-Perez, L.A., E. Agama-Acevedo, L. Sanchez-Hernandez and O. Paredes-Lopez (1999). Isolation and partial characterization of banana starches. Agric. and Food Chem., 47: 854–857.

Benzie, I.F.F. and J.J. Strain (1996). The ferric reducing ability of plasma (FRAP) as a measure of ‘‘antioxidant power’’: The FRAP Assay. Anal. Biochem., 239 (1): 70–76.

Bhaskar, J.J., S. Mahadevamma, N.D. Chilkunda and P.V. Salimath (2012). Banana (Musa sp. Var. Elakki bale) flower and pseudo-stem: Dietary fber and associated antioxidant capacity. J. Agric. Food Chem., 60: 427-32.

Borborah, K., S.K. Borthakur and B. Tanti (2016). *Musa balbisiana* Colla-taxonomy, traditional knowledge and economic potentialities of the plant in Assam, India. Indian J. Tradit Know., 15:116–120

Borges, C.V., V.B. de Oliveira Amorim, F. Ramlov, C.A. da Silva Ledo and M. Donato (2014). Characterisation of metabolic profile of banana genotypes, aiming at biofortified Musa spp. cultivars. Food Chem., 145: 496–504. DOI 10.1016/j.foodchem.2013.08.041.

Buragohain, R., G. Kalita and K. Sarma (2010). Nutritional significance of banana as swine feed. India Vet., 87 (3): 301-302.

Chen, H., G.L. Rubenthaler, H.K. Leung and J.D. Baranowski (1988). Chemical, physical, and baking properties of apple fiber compared with wheat and oat bran. Cereal Chem., 65 (3): 244–247.

Cordeiro, N., M.N. Belgacem, I.C. Torres and J.C. Moura (2004). Chemical composition and pulping of banana pseudo-stems. Ind. Crops Prod., 19 : 147-154.

Cordeiro, N., M.N. Belgacem, I.C. Torres and J.C.V.P. Moura (2004). Chemical composition and pulping of banana pseudo-stems. Indust. Crops and Prod., 19: 147–154.

Deng, G., O. Sheng, F. Bi, C. Li, T. Dou, T. Dong, Q. Yang, H. Gao, J. Liu, X. Zhong, M. Peng, G. Yi, W. He and C. Hu (2020). Metabolic Profiling in Banana Pseudo-Stem Reveals a Diverse Set of Bioactive Compounds with Potential Nutr. and Indust. Appl. Phyton-Int. J. Exp. Bot. Phyton, 89 (4): 1101 – 1126

Dikshit, P., M.K. Tyagi, K. Shukla, J.K. Gambhir and R. Shukla (2016). Antihypercholesterolemic and antioxidant efect of sterol rich methanol extract of stem of Musa sapientum (banana) in cholesterol fed wistar rats. J Food Sci Technol., 53 : 1690–1697.

Ganeshamurthy, A., G. Satisha and P. Patil (2011). Potassium nutrition on yield and quality of fruit crops with special emphasis on banana and grapes. Karnataka J. Agric. Sci., 24: 29–38.

Happi Emaga, T., C. Robert, S.N. Ronkart, B. Wathelet and M. Paquot (2008). Dietary fiber components and pectin chemical features of peels during ripening in banana and plantain varieties. Bioresource Technol., 99: 4346–4354.

Happi, E.T., A.R. Herinavalona, B. Wathelet, J. Tchango-Tchango and M. Paquot (2007). Effects of the stage of maturation and varieties on the chemical composition of banana and plantain peels. Food Chem., 103: 590–600.

Heywood, A.A., D.J. Myers, T.B. Bailey and L.A. Johnson (2002). Functional properties of low-fat soy flour produced by an extrusion-expelling system. Ame. Oil Chem. Soc., 79 (12): 1249–1253.

Ho, L.H., A.A.A. Noor and R. Bhat (2012). Mineral composition and pasting properties of banana pseudo-stem flour from *Musa acuminata* grown locally in Perak, Malaysia. Int. Food Res. J. 19 (4): 1479–1485.

Ho, L.H., T.C. Tan, A. Noor and M. Norlia (2017). Physical and Functional Properties of Banana Pseudo-stem Flour and its Effect on the Quality (Texture and Microstructure) of Formulated Bread. J. Agrobiotech., 8: 1–12.

Ibegbulem, C.O., E.O. Ayalogu and M.N. Uzoho (2003). Photochemical, anti-nutritional contents and hepatotoxicity of zobo (*Hibiscus sabdariffa*) drink. J. Agric. Food Sci., 1 (1): 35-39.

Joseph, M., A. Charles and R.V. Alex (2013). Phytochemical screening and bioactivity studies of *Phyllanthus wightianus*. J. Pharm. Res., 6: 188-192.

Juarez-Garcia, E., E. Agama-Acevedo, S.G. Sayago-Ayerdi, S.L. Rodriguez-Ambriz and L.A. Bello-Perez (2006). Composition, digestibility and application in breadmaking of banana flour. Plant Foods for Human Nutr., 61: 131–137.

Kallay, M. and Z. Kerenyi (1999). Occurrence and identification of procyanidins in hungarian grapes and wines. Hungarian Agric. Res., 4: 17–20.

Miller, G.L. (1959). Use of dinitrosalicylic acid reagent for determination of reducing sugar. Anal. Chem., 31 (3): 426–428.

Moller, J. (2009). Gravimetric determination of acid detergent fiber and lignin in feed: interlaboratory study. AOAC Int., 92 (1): 74–90.

Mosquera, O.M., Y.M. Correa, D.C. Buitrago and J. Nino (2007). Antioxidant activity of twenty five plants from Colombian biodiversity. Bioline Int., 102 (5): 631–634.

Mukhopadhyay, S., R. Fangueiro, Y. Arpac and U. Senturk (2008). Banana fibers– variability and fracture behaviour. Engineered Fibers and Fabrics, 3 (2): 39–45.

Ovando-Martinez, M., S. Sayago-Ayerdi, E. Agama-Acevedo, I. Goni and L.A. Bello-Perez (2009). Unripe banana flour as an ingredient to increase the undigestible carbohydrates of pasta. Food Chem., 113: 121–126.

Padam, B.S., H.S. Tin, F.K. Chye and M.I. Abdullah (2014). Banana byproducts: an under-utilized renewable food biomass with great potential. J. Food Sci. Technol., 51: 3527–3545.

Pareek, S. (2016). Nutritional and biochemical composition of banana (Musa spp.) cultivars. In: Simmonds MSJ, Preedy VR (eds) Nutr. Comp. Fruit Cultivars. Acad. Press, San Diego, 49–81.

Ponnuswamy, V., V. Devi and S. Vincent (2011). Bioprocessing of banana peel for production of amylase by Penicilliun sp. Asian. J. Exp. Sci., 2: 257–264.

Prieto, P., M. Pineda and M. Aguilar (1999). Spectrophotometric quantitation of antioxidant capacity through the formation of a phosphomolybdenum complex: specific application to the determination of vitamin E. Anal. Biochem., 269: 337-341

Rochana, A., T. Dhalika, A. Budiman and K.A. Kamil (2017). Nutritional value of a banana stem (Musa paradisiaca Val) of anaerobic fermentation product supplemented with nitrogen, sulphur and phosphorus sources. Pak. J. Nutr., 16:738–742.

Rodriguez, S.L., J.J. Islas-Hernandez, E. Agama-Acevedo, J. Tovar and L.A. BelloPerez (2008). Characterization of a fiber-rich powder prepared by liquefaction of unripe banana flour. Food Chem., 107: 1515–1521.

Rose, D.J., G.E. Inglett and S.X. Liu (2010). Utilisation of corn (*Zea mays*) bran and corn fiber in the production of food components. Sci. Food and Agric., 90: 915–924.

Saravanan, K. and S.M. Aradhya (2011). Polyphenols of pseudo-stem of different banana cultivars and their antioxidant activities. J. Agric. Food Chem., 59: 3613–3623.

Shaida, F.S., A.M. Nor, M.E. Ibrahim, M.S. Eng, A.B. Azliana and K.L. Supriatno (2011). Correlation between total phenolic and mineral contents with antioxidant activity of eight *Malaysian bananas* (Musa sp.). J. Food Comp. Anal., 24: 1-10.

Sharma, M., S.N. Patel, R.S. Sangwan and S.P. Singh (2017). Biotransformation of banana pseudo-stem extract in to a functional juice containing value added biomolecules of potential health benefts. Indian J. Exp. Biol., 55: 453–462.

Someya, S., Y. Yoshiki and K. Okubo (2002). Antioxidant compounds from banana (*Musa cavendish*). Food Chem., 79: 351–354.

Taher, M., L. Tadros and D. Dawood (2018). Phytochemical constituents, antioxidant activity and safety evaluation of Kei-apple fruit (*Dovyalis caffra*). Food Chem., 265: 144-151.

Tatjana, K., G. Terezija, K. Milica and A. Plestenjak (2002). Dietary fiber content of dry and processed beans. Food Chem., 80: 231–235.

Tiroutchelvame, D., M.M. Pragalyaashree and D. Peter (2019). Process Development for the Value Addition of Banana Central Core (Pseudo Stem). Int. J. Recent Technol. and Eng., 8 (4): 1055–1060.

Traynham, T.L., D.J. Myers, A.L. Carriquiry and L.A. Johnson (2007). Evaluation of water-holding capacity for wheat-soy flour blends. Ame. Oil Chem., 84: 151–155.

Vilela, C., S.A. Santos and J.J. Villaverde (2014). Lipophilic phytochemicals from banana fruits of several Musa species. Food Chem., 162: 247–252.

الخصائص التركيبية والوظيفية لساق الموز

أماني حفناوي طه - احمد السيد عوض - خالد محمد محمد وهدان - محمود عبدالرزاق دهيم

قسم الكيمياء الحيوية – كلية الزراعة – جامعة الزقازيق – مصر

تم إجراء هذا البحث لتقييم الاختلافات في التركيب الكيميائي والملامح الوظيفية لدقيق جذع الموز الأصلي (T_1) ولب طري لدقيق الموز الساق الكاذبة .(T_2) أشارت التحليلات الكيميائية إلى أن المحتويات القريبة (رطوبة، دهون، بروتين، رماد) كانت أعلى بشكل معنوي في (T_2) عنها في (T_1) كانت مستويات الألياف الغذائية الكلية والألياف الغذائية غير القابلة للذوبان واللجنين والهيميسليلوز والسليلوز أعلى في (T_1) من (T_2)، بينما لم يكن هناك فرق معنوي في الألياف الغذائية القابلة للذوبان. يحتوى (T_1) أيضًا على محتوى أعلى من البوليفينول والفلافونويد مقارنة بـ (T_2) كانت كل من القدرة المضادة للأكسدة والقدرة على إزالة الشقوق الحرة أعلى في (T_1) منها في . (T_2) من ناحية أخرى ، أظهر (T_2) قدرة على الاحتفاظ بالماء وقابلية الذوبان، على الرغم من أن قدرته على الاحتفاظ بالزيت كانت أقل من (T_1) نستنتج أن دقيق ساق الموز الكاذب هو مكون غذائي وظيفي محتمل للمنتجات التي تحتوي على نسبة عالية من الألياف الغذائية. كم تم إجراء فحص كيميائي نباتي على مستخلص الماء ومستخلص الإيثانول. تشير نتائج الاختبارات الكيميائية النباتية التي تم الحصول عليها إلى وجود مركبات فينولية: الفلافونويد، القلويات، التانينات، الصابونين، المنشطات ، والجليكوزيدات.

المحكمـــــون:

1- أ.د. محمـــد جـابـر طـــــه أستاذ الكيمياء الحيوية – كلية الزراعة – جامعة الأزهر.

2- أ.د. أيمن محمد السيد جمعة أستاذ الكيمياء الحيوية – كلية الزراعة – جامعة الزقازيق.