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Physicochemical and Functional Properties of Pulp and Peel Flour of Dried Green and Ripe Banana (Cavendish)

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Abstract **– The need for improved health lead the consumers to seek out specific foods or physiologically active food components. The large amount and the low cost of cull bananas are a convincing reason to determine the nutritional and industrial value of banana flour as a functional food. This study aimed to determine the chemical and nutritional profile of fresh green and ripe banana pulps and their peels flour, in addition to the functional properties (water holding capacity and oil holding capacity at 40, 60 and 80 C) of banana flour, which were obtained by oven drying. Standard methods of AOAC were used to determine the approximate composition of the banana flour, while minerals and ascorbic acid were determined by flame photometer and colorimeter respectively. Samples of banana flour were also evaluated for physicochemical properties such as pH, total soluble solids and titrable acidity. These tests were carried out at the Laboratory of Food Analysis, Faculty of Engineering and Technology, University of Gezira. The study proved the possibility of promoting the use of banana that could have been wasted as unnecessary and this was manifested in green banana pulp flour, which was found to be a good source of potassium and calcium with an average of 334mg/100g and 87mg/100g respectively. All types of banana flour are good source of fiber, especially green banana peel in which the average fiber content was found to be 6.4g/100g, this can be an important ingredient when the aim is to increase the non-digestible fraction in food and may have positive effects on health. The green and ripe banana pulps flour possessed the highest value of protein and vitamin C with an average of 0.7% and 0.1mg/100g, respectively. Concerning physicochemical and functional properties, the total Sugar content (8mg/100gm) and the total Soluble Solids (5 mg/100gm) for ripe banana pulp were found to be increased with ripening. Highest water holding capacity among all banana flour samples was recorded for ripe banana peel flour (9.2 g water/g dry sample). Good oil absorption capacity of the flour was measured in green banana peel flour (1.8 g oil/g dry sample). This study suggested the use of banana flour in the preparation of food products for digestion disease patients, binding agent, and as a filling agent besides adding nutritional value to the food products. Future work should aim at studying stability, optimum storage conditions, and suitable packaging requirements.**

Keywords **– Physiochemical Characteristics, Functional Properties, Banana, Peels, Pulps.**

Abbreviations **– Banana samples: Ripe Banana Pulp (RBP) - Green Banana Pulp (GBP) - Ripe Banana Peel (RBPE) - Green Banana Peel (GBPE).**

INTRODUCTION

The need for improved health lead the consumers to seek out specific foods or physiologically active food components, also called the functional food. In recent years, the term functional, applied to food, has taken different connotation that is to provide an additional physiological benefit, beyond the basic nutritional needs (Oi *et al.,* 2012). Lately, green banana and banana peel were considered as functional food. The large amount and low cost of cull bananas is a convincing reason to undertake a determination of the nutritional and industrial value of banana flour. Banana is one of the most important fruit crops in the world Total world production increased from 46,756,000 tons in 1989 to 58,434,000 tons in 1999 and producing countries are, India, Ecuador, Brazil, and China *(*FAO, 2007*)*. Sudan banana is the most widely consumed fruit due to its good taste, low price, high nutritional value, and availability all through the year. It is grown in almost every state with annual production of 540 thousand metrictons, which accounts for 27 % of total production of Arab countries (AOAD, 2008). Banana fruits are highly perishable and subjected to fast deterioration, as their high moisture content and high metabolic activity persist after harvest (Demirel and Turhan, 2003). Rejected bananas are normally disposed of improperly, in some countries such as Costa Rica, dumping of the rejected bananas into rivers is a common practice. The high carbohydrate content of the crop creates high biochemical oxygen demand (BOD) in the rivers and, hence, reduces aquatic animal populations. so banana can be processed in various ways thus they may be stored for longer periods and utilized or other purposes. New economic strategies are now considered for banana use, such as the production of green banana flour, and to incorporate the flour into various innovative products such as slowly digestible cookies (Aparicio-Saguilan*,* 2007), high-fiber bread (Juarez-Garcia *et al.,* 2006) and edible films (Rungsinee and Natcharee, 2007). It is low – cost ingredient for food industry and an alternative to minimizing banana wastes (Zhang *etal*, 2005). The advantages of green banana flour include the content of high total starch (73.4%), resistant starch (17.5%) and dietary fiber content (14.5%) (Juarez-Garcia *et al., 2006)*. Green banana flour might be an important source of polyphenol, compounds that are regarded as natural antioxidants (Vergara and Valeneia *et al.,* 2007). In addition, it can be used in place of traditional thickeners such as wheat, soy, and cassava starch and cornstarch, improving the nutritional value and assuming the taste of the foods. In addition to vitamins A, C and B complex (B1, B2 and niacin) banana fruit contains minerals essential for the proper functioning of the human body (Freitas and Tavares*,* 2005). Ripe banana flour can potentially offer new products with standardized composition for various industrial and domestic uses, it also offer high sugar content to dishes requiring sweetness (Abbas *et al.,* 2009). The amount of fruit waste from the peels is expected to increase with the development of processing industrials that utilize the green and ripe banana. The banana peel represents about 40% of the total weight of fresh banana (Tchobanoglous *et al,* 1993*)*. The banana peel is rich in antioxidant compounds (Someya *et al.,*2002) which implying the potential value of the peel in terms of antioxidant content, Perhaps in the future it may be possible for technologist to mix and match the pulp and peel flour in order to achieve techno functional properties without sacrificing the aesthetic values of their products. This development can spur the utilization of banana peel as innovative ingredients in various foods.A s far as we know, no study has been conducted to compare physicochemical and functional properties of banana flour prepared from pulp and peel of green and ripe banana in Sudan.

Materials and Methods

Raw materials, Chemicals and Equipment's

These include ripe and green banana and fresh lemon fruits which is used to reduce the enzymatic browning. All research materials were purchased from Wad Medani local market. Sulphuric acid - sodium hydroxide- boric acid- hydrochloric acid- hexane- oxalic acid- 2, 6, dicholorophenolinddophenol- ascorbic acid- enthrone solution a citric acid. Hot air oven- Spectrophotometer, Atomic absorption Spectrophotometer, pH-meter, Refractormeter and Centrifuge.

Methods

Preparation of Banana Pulp and Peel Flour

Banana fruits (ripe and green) were sorted from injured fruits, then washed under running tap water, weighed and peeled. Pulp and peel were reweighed and then cut into 1 cm slices using sharp clean stainless steel knife. The slices of both (peel and pulp) were immediately dipped in the lemon solution (2.5%) for 3 minutes to reduce enzymatic browning. The treated banana sample slices were spread on perforated stainless steel trays (45 cm wide, 75 cm length and 7 cm height) separately. Banana slices (2kg)were loaded on a perforated stainless steel trays and left to dry in hot air oven (70°C) over night. The dried banana samples were grounded using house hold grinder and the resulted flour was reweighed then storedat 25 - 27°C in sealed lastic bags separately for further analysis. The yield of obtained banana samples flour was calculated by dividing the amount of pulp or peel flour by the amount of fresh pulp or peel.

Proximate Analysis

The total protein content of samples was evaluated using a FOSS nitrogen analyzer (DK-3400; Hilleroed, Denmark) with a conversion factor of 6.25. Fat, moisture, fiber, and ash contents were determined using standard AOAC methods 932.06, 925.09, 985.29, and 923.03, respectively (AOAC, 1990). The carbohydrate content was determined according to James, (1996).

Ascorbic Acid Content Determination

Vitamin C content estimated as ascorbic acid according to the method of described by Ruck, (1963). Three gm of fresh banana samples and their flour were blended with reasonable amount of 0.4% oxalic acid (4gm/liter) and filtered by what man (no.1) filter paper. Then the samples volume completed to 250ml with 0.4% oxalic acid. Then, 20ml of filtrate were pipette into a conical flask and titrated with a known strength 2, 6- dicholorophenolinddophenol until a faint pink color appeared. The dye strength determined by taking 5ml oxalic acid 10% (50gm/500ml) and added to 5ml standard ascorbic acid (0.05gm/250ml oxalic acid 10%). Then titrated with 2, 6- dichlorophenolindphenolindophenols (0.2gm /500ml) to a faint pink color.

Total Sugars Content Determination

Three gm. of each sample were mixed with 50 ml distilled water, then one ml of the solution was transferred to attest tube, then 2 ml of anthron solution were added, mixed thoroughly and left to cool down at room temperature . The color intensity of the samples has been read using spectrophotometer at wavelength 620nm.

Reducing Sugar Content Determination

The reducing sugar content of fresh banana samples and their flour were estimated. One ml of the sample was mixed with one part of solution B and four parts of solution A. The mixture was boiled in water bath for 25-30 minutes, and then it was cooled under running tape water, and after that one ml of Nelson reagent was added. The optical density (O.D) of the samples has been read using spectrophotometer at wavelength 520 nm.

Minerals Content Determination

Minerals content of the fresh banana samples and their flour were determined according to Chapman and Pratt method, (1982). One gm of sample of 1g was weighed in a clean dry porcelain crucible and placed into a muffle furnace at 550°C for 24 hr. Then, the ash content in the crucible was cooled and 10 ml of (2.0N) hydrochloric were added to each crucible and placed in a hot sand bath for about 10-15 minutes. The ash solution of each sample was filtrated with filter paper No. 4 and the filtrate was made up to volume in a volumetric flask (100 ml) with hot distilled water. Finally the concentrations of sodium, potassium, iron, calcium and phosphorus in the sample solution were determined by using atomic absorption spectrophotometer.

pH, Titrable Acidity and Total Soluble Solid Determination

The pH of the fresh banana samples and their flour were estimated according to the Suntharalingam and Ravindran, (1994).The pH of the flour was measured using a pH meter, model 10. Flour suspension (8% W/V) was stirred for 5 min, allowed to stand for 30 min, filtered and the pH of filtrate was measured. The TSS content of banana samples flour was estimated according to the Salvaador *et al,* (2007) method. TSS in the same flour slurries (8% W/V) were measured using a refractmeter. The titrable acidity was determined according to the method described by person, (1973). Bravely, Three gm of banana samples flour were weighed accurately, dissolved in distilled water by stirring for 15 minutes, then filtered using what man filter paper (No.4) and then transferred to 100 ml volumetric flask to complete the volume up to the mark. 5ml of the prepared solution were titrated against 0.1N Sodium hydroxide using phenolphthalein as an indicator, and then was calculated as citric acid (%) of an equivalent weight of 64. The percentage of TA content was calculated using the following formula:

$$\text{Citric acid \%} = \frac{\text{Titer} \times 0.1\text{N (NaoH)} \times \text{Equivalents weight} \times \text{Dilution factor} \times 10}{\text{Weight of the sample} \times 1000}$$

Water Holding Capacity (WHC) and Oil Holding Capacity (OHC)

The WHC and OHC character is tie of banana samples flour were determined according to the Rodrigue-Ambriz *et al.,* (2008). Breuer, Twenty-five milliliters of distilled water or and commercial olive oil were added to 1gm. of dry samples, stirred and incubated at 40, 60 or 80°C for 1h. Tubes were centrifuged at 3000xg for 20 min, the supernatant was decanted and the tubes were allowed to drain for 10min at a 45 angle. The residue was weighed and WHC and OHC calculated as g water or oil per g dry samples, respectively.

Statistical Analysis

Analyses were done in triplicate. Analysis of variance (ANOVA), followed by fishers protected LSD $P< 0.05$ tests with a significant level were performed on the data (Gomez, 1984).

Results and Discussion

Proximate Analysis

Moisture content of GBP, GBPE, RBP and RBPE was found to be 62.1%, 84.9 %, 73.3% and 92.4%, respectively, which is found to be within the range of results reported by Adeyemi and Oladiji, (2009). It was approved that moisture content in pulp increases with ripening due to respiratory break down of starches into sugars and migration of moisture from peel to pulp (Marriott *et al,* 1985). As shown in Table 1, RBPE posses the highest ash content which may be due to gradual incensement of ash content from green to ripe stage as revealed by Adeyemi and Oladiji, (2009).The results of protein shows that protein content increased during fruit ripening as it was confirmed earlier by Loeseck, (1950) and Lustre, (1976). On the other hand, the results of banana protein does not cope with the values (3.8-4.2%) found by Akaninwor and Sodje, (2005) and this may be due to genetic type, variety and climate (Table 1).

Table 1. Proximate Composition (%) of green banana pulp (GBP), green banana peel (GBPE), ripe banana pulp (RBP) and ripe banana peel (RBPE).

Banana samples	Moisture	Ash	Protein	Fiber	Fat	Vitamin c (mg\100g)	Total Sugar	Reducing Sugar
GBP	62.1	0.6	0.4	0.34	1.74	0.09	3.96	3.21
GBPE	84.9	0.13	0.04	0.84	2.08	0.09	6	4.00
RBP	73.3	0.9	0.5	0.14	1.89	0.09	21	13.0
RBPE	92.4	0.33	0.04	0.71	2.12	0.18	24	15.0

The fiber content in Table 1, ranged from 0.14 to 0.84%. The results revealed that fiber value decreases through ripening phases. Furthermore the fiber value of the RBP (0.14%) obtained is lower than the results (2.39%) reported by Forster *et al.,* (2003).The fat content was ranged from 1.74 to 2.12% with the order: GBP<RBP<GBPE<RBPE. Results Showed that GBP contain the lowest value of fat (1.74%). This result was higher than that reported by Wills *et al*, (1998) (0.1%). This is may be due to the difference in cultivars used.

Ascorbic Acid Content (Vitamin C)

Table 1, Figure1, illustrated the results of ascorbic acid content it was found to be (0.09mg/100gm), (0.09mg/100gm), (0.09mg/100gm) and (0.18mg/100gm) for GBP, GBPE, RBP and RBPE, respectively. The results obtained were less than the values reported by Forester *et al,* (2003) who showed that ascorbic acid of banana pulp range from 5.35 to 13.06 mg/100gm with highest value in RBPE and same value for all others samples. The variability of Vitamin C content in banana fruits is due to the effect of various factors such as genotypic differences, per harvest climacteric condition, culture practice, and maturity, harvesting method and post-harvest handling procedure as it was reported by Lee and Kader, (2000).

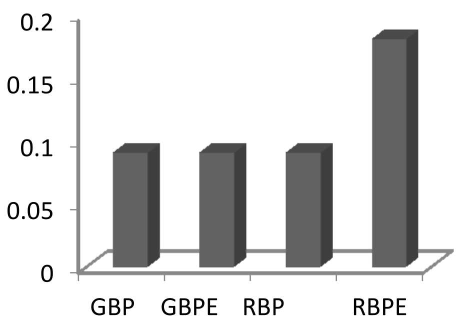

Fig. 1. Ascorbic acid content (mg/100gm) of green banana pulp (GBP), green banana peel (GBPE), ripe banana pulp (RBP) and ripe banana peel (RBPE).

Total Sugar Content

Sugar content in the fresh banana pulp and peel was found to be 3.96, 6, 21, 24 % for GBP, GBPE, RBP and RBPE respectively, the results of GBP and RBP were in the range of the results reported by Lii *et al,* (1982) (6% for GBP and 27% for RBP) who attributed this to hydrolysis of starch into sugars during banana ripening.

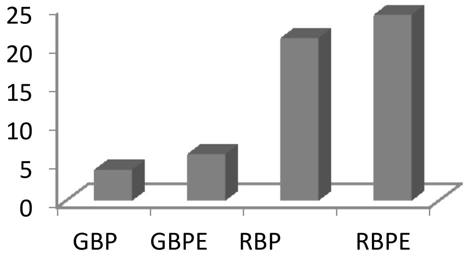

Fig. 2. Total sugar content (%) of green banana pulp (GBP), green banana peel (GBPE), ripe banana pulp (RBP) and ripe banana peel (RBPE).

Reducing Sugar Content

Figure 3, shows reducing sugars content which was found to be 3.21, 4, 13, and 15 % for GBP, GBPE, RBP and RBPE, respectively. The data obtained has the same trend of results reported earlier by Lii *et al*, (1982), who recorded that reducing sugar content for GBP is 1.3% while for RBP is 12.4%.

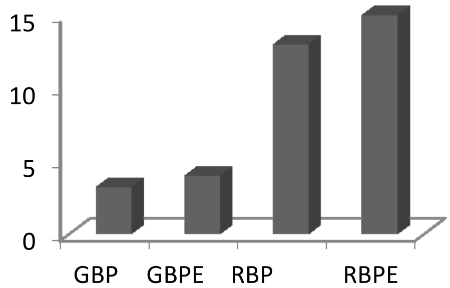

Fig. 3. Reducing Sugar content (%) of green banana pulp (GBP), green banana peel (GBPE), ripe banana pulp (RBP) and ripe banana peel (RBPE).

Minerals Content

Minerals content are shown in Table 2, Potassium has the highest content among measured minerals for all samples it was found to be 376.6, 303.3, 316.6 and 300 mg/100gm for GBP, GBPE, RBP and RBPE, respectively, The pulp have higher value of mineral than that detected by Mohaparta *et al.,*(2010), they reported values of 218, 4.9 mg/100gm for potassium and calcium, respectively. This variation in minerals contents could be attributed to the composition of the soil and environment in which the plants grow as confirmed earlier by Forester *et al.,* (2003).

Table 2. Minerals content of green banana pulp (GBP), green banana peel (GBPE), ripe banana pulp (RBP) and ripe banana peel (RBP):

Banana Sample	Sodium (mg/100gm)	Potassium (mg/100gm)	Calcium (mg/100gm)
GBP	45	376.6	140
GBPE	54	303.3	50
RBP	60	316.6	116.8
RBPE	70	300	43.3

pH Determination

The pH of banana flour samples was ranged between 6.3 to 7.5. RBPE flour showed the highest pH whilst RBP flour showed the lowest.

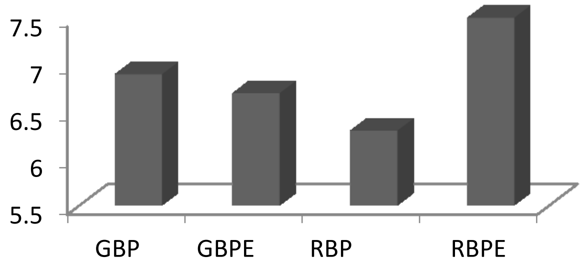

Fig. 4. Determination of pH of flour of green banana pulp (GBP), green banana peel (GBPE), ripe banana pulp (RBP) and ripe banana peel (RBPE).

Total Soluble Solids (TSS)

The TSS ranged between 1.4 to 5 with the order: RBP> RBPE> GBPE>GBP. T.S.S indicates soluble solid content of flour, and high T.S.S has been associated with high sucrose content in banana pulp (Buga nd *et al.,* 2006). It has been reported that the average starch content drops from 70% to 80% in the Pre-climacteric period to less than 1% at the end of the climacteric period, while sugars, mainly sucrose, accumulate to more than 10% of the fresh weight of the fruit (Zhang *et al*, 2005). The lower TSS of green banana flour is acceptable science it is known that amylase, glycosidase, phosphorylase, Sucrose syntheses and inverts can act in the degradation of starch and the formation and accumulation of soluble sugars (Emaga *et al, 2007;* Terra *et al,* 1983). Since TSS of RBP was higher than RBPE, it can be concluded that RBP had higher sugar content than RBPE flour. In principle, this could cause less sweetness to be perceived in RBPE flour which in turn could influence consumer acceptance. This suggestion however, needs further testing. Three types of soluble sugar, ie, sucrose, glucose and fructose that have been detected in banana peel may represent the TSS of peel flour (Emaga et al, 2007).

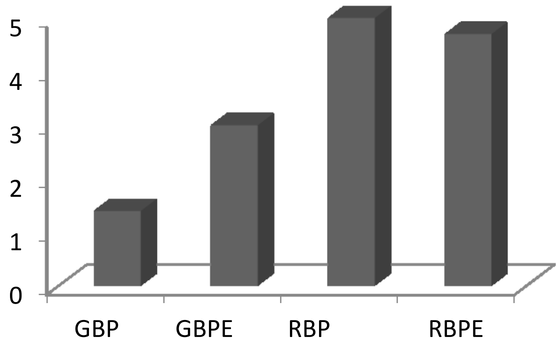

Fig. 5. Total soluble solids content (%) of flour of green banana pulp (GBP), green banana peel (GBPE), ripe banana pulp (RBP) and ripe banana peel (RBPE).

TITRABLE ACIDITY (TA)

The results in Table 3, Figure 6, showed the variability in titrable acidity between the samples. The GBP flour recorded the highest acidity value (3.30%), followed by RBP (3.06%), GBPE (2.11%) and lowest value was observed for RBPE flour (1.83%), this is assuring that acidity decreases through ripening stages, as confirmed earlier "Unripe fruits are usually starchy and acidic in taste, hard in texture and sometimes astringent. After ripening, they become sweet, soft and highly flavored, as greatly acceptable as human food" (Mattoo *et al*., 1975).

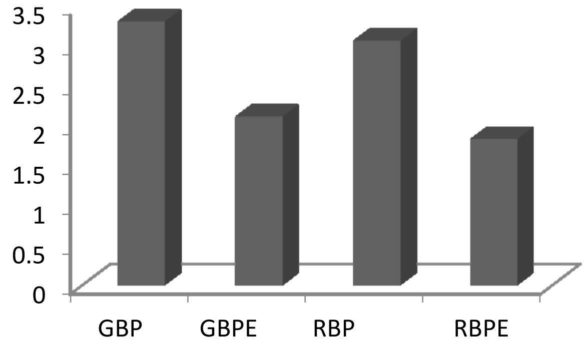

Fig. 6. Tirtrable acidity content (%) of flour of green banana pulp (GBP), green banana peel (GBPE), ripe banana pulp (RBP) and ripe banana peel (RBPE).

Table 3. Physiochemical properties of green banana pulp (GBP), green banana peel (GBPE), ripe banana pulp (RBP) and ripe banana peel (RBPE)

Banana samples	pH	T.S.S	T.A
GBP	6.9b	1.4d	3.30a
GBPE	6.7b	3c	2.11b
RBP	6.3c	5a	3.06a
RBPE	7.5a	4.7b	1.83c

Mean values in a column with different letters are significantly different.

Functional Properties

Water Holding Capacity (WHC)

WHC of all flour samples increased with temperature increasing, and ranged between 0.7 to 9.2 g/g dry samples. RBPE flour possesses the highest value of WHC at 80°C (9.2 g /g dry sample) on the other hand RBP flour showed the lowest value of WHC (2.5 g/g dry sample) at the same temperature. WHC could be related to the physical state of starch (Waliszewsld *et al,* 2003) dietary fiber and protein in the flour. According to Rodriguez- Ambriz *et al,* (2008), amylase has the capacity to effectively bind water molecules, yielding a higher WHC. However since starch was low in RBPE (Emaga *et al.*, 2007), the high WHC noted in RBPE could be attributed to the dietary fibers and protein. The increase in WHC at 80°Cin all flour samples was partially due to protein denaturation, solution properties of dietary fiber such as hemicelluloses and pectin polysaccharides (Zhang *et al.,* 2005), and to a smaller extend to the gelatinization of starch in the flour that absorbs water into starch granules with concomitant swelling (Rodriguze-Ambrize *et al.,* 2008).

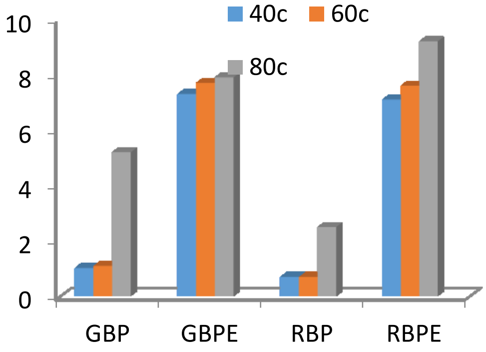

Fig. 7. Water holding capacity (g/g dry sample) of flour of green banana pulp (GBP), green banana peel (GBPE), ripe banana pulp (RBP) and ripe banana peel (RBPE).

Table 4. Water holding capacity and Oil holding capacity of flour of green banana pulp (GBP), green banana peel (GBPE), ripe banana pulp (RBP) and ripe banana peel (RBPE)

Banana Sample	WHC			OHC		
	40°C	60°C	80°C	40°C	60°C	80°C
GBP	1.02c	1.1b	5.2c	1.04b	1.06c	1.08c
GBPE	7.3a	7.7a	7.9b	1.2a	1.4a	1.8a
RBP	0.7d	0.7c	2.5d	0.8c	0.8d	1.04d
RBPE	7.1b	7.6a	9.2a	0.2d	1.2b	1.4b

WHC: water holding capacity; g water/g dry sample, OHC: oil holding capacity; g oil/g dry sample. Mean values in a column with different letters are significantly different.

Oil Holding Capacity (OHC)

The OHC of all tested samples increased with temperature increment, and it ranged from 0.2 at 40°C to 1.8 at 80°C g oil/g dry samples. These values are lower than that reported in fiber-rich banana powder that could hold 2.2 gm oil/ gm dry sample. OHC relates to the hydrophilic character of starches present in the flour (Rodriguez-Ambriz *et al.,* 2008) that is present in high quantity in green flour (Rodriguez- Ambrize *et al.,* 2008 ; Zhang *et al.,* 2005) , and in reduced quantity in ripe flour.

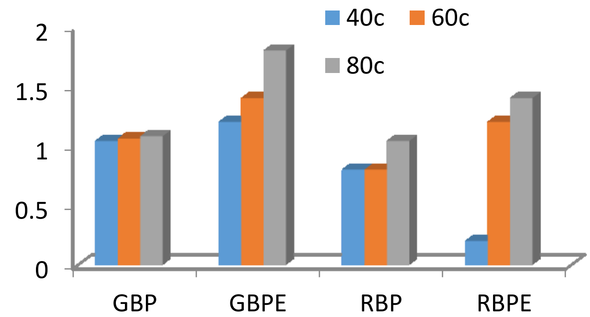

Fig. 8. Oil holding capacity (g/g dry sample) of flour of green banana pulp (GBP), green banana peel (GBPE), ripe banana pulp (RBP) and ripe banana peel (RBPE).

Conclusion

Due to the high content of functional ingredients, regular consumption of green banana flour can be expected to confer beneficial health benefits for humans. Based on the physicochemical properties results and analysis conclusion can be drawn, that flours prepared from pulp and peel of ripe and unripe banana (Cavendish variety).The high content of fiber in green banana peel flour indicated that they are a healthy choice for consumption especially when the aim is to increase the non-digestible fraction in food and may have positive effects on health. The characteristics found indicate a promising use of green and ripe banana peel flour specially in food preparations that involve water binding as in sausage production or and oil mixing, such as in bakery products where oil is an important ingredient, besides adding nutritional value to food products, also this stands out for not creating waste, thus representing the complete use of the fruit.

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