International Journal on Food, Agriculture, and Natural Resources
Volume 05, Issue 03, Page 125-132
ISSN: 2722-4066
http://www.fanres.org

Original Paper

Nutritional and Functional Characteristics of Senescent Plantain Powder Mix

Doreen Dedo Adi[1], Ibok N. Oduro[2], Charles Tortoe*

1) *Department of Hospitality and Tourism Education, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, P. O. Box 1277, Kumasi, Ghana*
2) *Kwame Nkrumah University of Science and Technology, Department of Food Science and Technology, Kumasi, Ghana*

*) *Corresponding Author: ddadi@aamusted.edu.gh*

Received: 24 Mei 2024; Revised: 21 September 2024; Accepted: 25 September 2024
DOI: *https://doi.org/10.46676/ij-fanres.v5i3.350*

***Abstract*— Post-harvest loss of plantain peeks at senescence. Drying senescent plantain enhances its culinary applications. This study aimed to determine the biochemical and functional properties of foam-mat dried senescent plantain samples, and their respective powdered mixes prepared for baking ofam (an Indigenous spicy cake). The nutritional benefits of foam-mat dried senescent plantain, with its high vitamin C and total carotenoid content, make it a valuable addition to dietary interventions. Foam-mat dried plantain samples and their respective powdered mixes were evaluated for their proximate composition, vitamin C, total carotenoids, amino acid contents, water and oil absorption capacities, and least gelation concentration using standard methods. The products were predominantly carbohydrates (73.3g - 80.4g/100g) with low moisture contents (9.19 - 20.68 g/100g). Vitamin C and total carotenoids ranged from 17.42 mg/100g to 33.99 mg/100g and 3.4 to 7.2 µg/g respectively. The samples had appreciable amounts of calcium (78.90 - 175.18 mg/100g), magnesium (112.13 - 113/79 mg/100g), potassium (95.76 - 77.09 mg/100g), iron (17.65 - 12.76 mg/100g) and zinc (10.94 - 15.82 mg/100 g). The most abundant amino acids were phenylalanine, histidine, methionine and aspartic acid. Sample SPPFSCF exhibited the best gelation capacity (22 g/100 mL). The water absorption capacities of the samples were influenced by the flour type used. However, the variations in the oil absorption capacities of the powdered mixes were statistically insignificant. EAPFRCF absorbed the least oil (0.84 g/g) while SPPFSCF absorbed the most (0.94 g/g). Foam-mat dried senescent plantain and their powdered mixes have the potential for utilization in nutritional interventions. Its low moisture content will support a longer shelf-life than the fresh overripe plantain.**

Keywords*— *Foam-mat drying, Nutritional characteristics, Ofam powdered mix, Senescent plantain,

I. INTRODUCTION

Senescent plantain is a good source of nutrition for consumers in growing areas, especially in the global South. It is used for snack products such as cakes, fritters, beverages, jams and vinegar [1]. Senescent plantains have high sugar and moisture content and deteriorate rapidly [2]. The very nature of senescent plantains makes them challenging to dry. The sugars in senescent plantains are glucose, fructose, sucrose, maltose and rhamnose, the last two being in very minute quantities [3, 4]. It is a good source of minerals such as iron (Fe), phosphorus (P), potassium (K) and even calcium (Ca). These minerals are essential to proper body function.

The mineral concentration of plantain varies depending on their geographical location and ripeness. In the works of Hardisson et al. [5] and Forster et al. [6], they observed significant differences in the amount of Potassium (K), Magnesium (Mg) and Phosphorus (P) in the same species of banana found at different locations on an island. This phenomenon was also observed for minerals such as Iron (Fe), Copper (Cu), Zinc (Zn), Calcium (Ca) and Sodium (Na). Izonfuo and Omuaru [7] observed an increase in plantain pulp ash and macromineral contents during ripening. Adeyemi and Oladiji [8] similarly, observed an increasing trend in fruits' ash and mineral contents during ripening. Carotenoids and vitamin C are the two most important vitamins found in significant amounts in plantains [9]. Major carotenoids identified in ripe banana fruits are lutein, α-carotene and β-carotene, most of which are found in the peels and relatively low amounts in the pulp [10, 11, 12, 13].

Carotenoids in banana fruits are temperature-dependent. Fruits ripened at 35ºC and have higher carotenoid levels in the peels than those ripened at lower temperatures, where the carotenoid levels remain relatively constant [14]. Some researchers have indicated that carotenoid levels increase during maturation and ripening. However, Innocent et al. [15] observed reduced β-carotene levels in ripe plantains compared to their unripe counterparts. They also indicated that cooking methods such as steaming, charcoal roasting and frying significantly reduce the levels of β-carotene and vitamin C in plantains and sweet potatoes. The loss of vitamin C in fried plantains has also been reported by Rojas-Gonzalez et al. [16]. This is expected as vitamin C is a heat-sensitive water-soluble vitamin [17]. Predictably, the provitamin A content of banana fruits varies and depends on the fruit pulp color [18]. The yellow and orange varieties have recorded provitamin A levels as high as 3500 µg/100g on a fresh weight basis [18]. Other vitamins such as niacin (700 µg), pantothenic acid (370 µg), riboflavin (50 µg) and thiamine (50 µg) have been identified in plantain pulp [3,

19, 20]. Ripe plantain pulp is low in protein but has essential amino acids [21]. Despite the nutritional contribution of senescent plantain to the human diet, there is a need for processing to extend shelf life and enhance utilization due to its rapid deterioration. The application of foam-mat drying techniques has made drying of the senescent plant possible. Dried senescent plantain has potential applications in the bakery industry. Earlier studies have successfully formulated an acceptable powdered mix from dried senescent plantains for preparing an indigenous spicy cake known as ofam. The formulated powdered mixes are expected to have a peculiar nutritional composition different from their ingredients. However, the functional properties of the powdered mixes are yet to be investigated. This study aims to determine the nutritional composition and functional properties of formulated senescent plantain powdered mixes.

II. Materials And Methods

A. Sources of raw materials

Matured plantains at ripening stage 1 were harvested at JE farms in Mankesim in the Central Region. The plantains were de-handed, kept on a bench in a room at ambient temperature (27 ℃), and allowed to ripen to stage 9 for processing. At ripening stage nine, the plantain samples were washed, peeled, packaged in Ziploc bags (in 1 kg portions), and kept frozen for further use. Powdered table salt, onion powder (Badia), ginger powder, African pepper, calabash nutmeg, dried cayenne and unrefined palm oil was obtained from a local market in Accra. Steeped corn flour (SCF) and roasted corn flour (RCF) were obtained from the processing unit of the Food Research Institute (FRI) of the Council of Scientific and Industrial Research (CSIR).

B. Preparation of foam mat dried senescent plantain

Senescent plantain samples were washed, hand peeled, sliced with a kitchen knife to 5 mm thickness, and steam blanched using a rational self-cooking centre (dual combi steamer/oven) at 100 ºC for 5 min. A weighed amount (200 g) of pulp was blended with 100 mL of water using a warring blender (model 51BL30, PA USA) for 2 minutes to form a smooth paste. The plantain puree was mixed with a foaming agent with a ratio of 93.75% plantain to 6.75% foaming agent. The foaming agent concentration was based on a preliminary study. The mixture was whisked using a 5-speed control Rival hand mixer (HM 1002-ET, Guangdong, China) at speed setting 5 to attain a foam density of 0.5 g/mL. The foams were dried on rectangular trays at a foam thickness of 1 cm at 70ºC for 7 hours using a forced air dryer. The dried plantain foam mats were cooled at 18ºC for 4 minutes to obtain a crisp, easy-to-mill product. The dried foam mat was milled, packaged into Ziploc bags, and stored in a desiccator for further analysis.

C. Sample preparation

The formulation for the powdered mix is presented in Table 1. The ingredient composition is based on optimization studies of foam. Weighed amounts of the plantain foam mats are mixed with other ingredients such as flour, and powders of ginger, onion, African pepper, cayenne pepper, and calabash nutmeg as presented in the formulation table. The mixture was milled in an electric grinder to obtain the powdered mix. The powder mix was sieved with a sieve aperture of 250 µm and packaged in a vacuum sealer bag for further analysis (Figure 1).

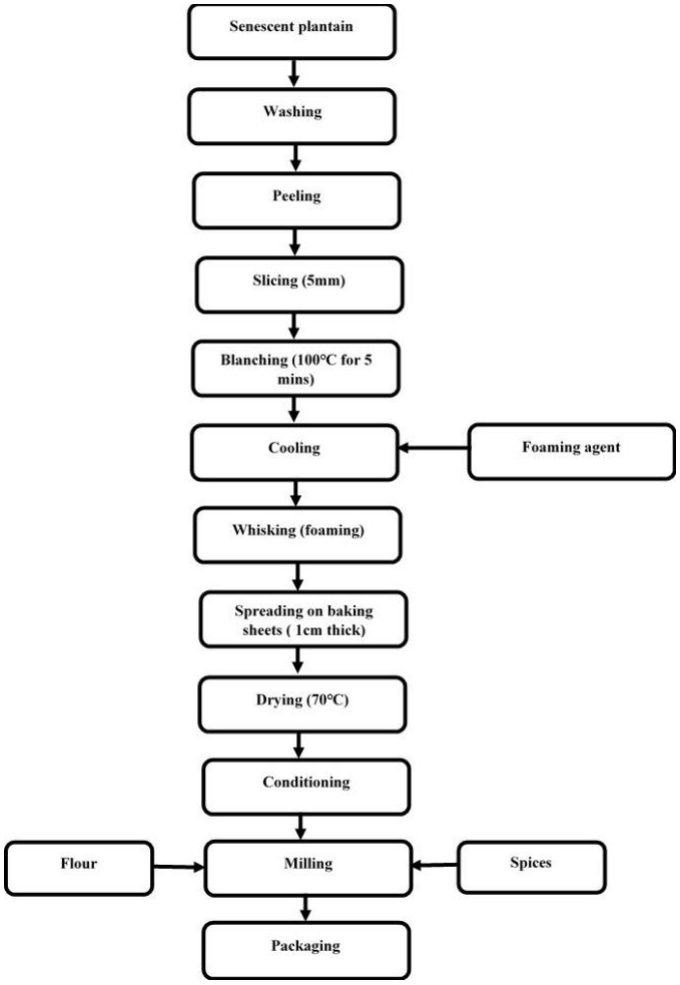

Fig. 1. Process flow diagram for senescent plantain powdered mix

1) Proximate analysis

The moisture (AOAC 925.10), crude protein (AOAC 984.13), crude fat (AOAC 920.39C), ash (AOAC 923.03), and crude fibre (AOAC 962.09) contents of the samples were determined by standard methods [22, 23]. The difference determined the total carbohydrate. The energy value was calculated as the sum of the mean protein, fat and carbohydrate values multiplied by their respective Atwater factors 4, 9 and 4 [24].

TABLE 1. DESCRIPTION AND COMPOSITION OF SAMPLES FOR ANALYSIS

Sample ID	Sample Description	Amount of ingredients added (g)							
		Plantain	**Flour SCF**	**RCF**	**Ginger**	**Onion**	**African pepper**	**Cayenne pepper**	Calabash nut meg
EAPF	Egg albumen plantain foam mat								
EAPFRCF mix	*Ofam* powdered mix prepared from egg albumen plantain Foam mat using roast corn flour as binder	241.7	-	114.7	16	50	4	16	**0.5**
EAPFSCF mix	*Ofam* powdered mix prepared from egg albumen plantain Foam mat using steeped corn flour as binder	241.7	114.7	-	16	50	4	16	**0.5**
SPPF	Soy protein plantain foam mat								
SPPFRCF mix	*Ofam* powdered mix prepared from soy protein plantain Foam mat using roast corn flour as binder	242.1	-	111.2	16	50	4	16	**0.5**
SPPFSCF mix	*Ofam* powdered mix prepared from soy protein plantain foam mat using steeped corn flour as binder	242.1	111.2	-	16	50	4	16	**0.5**

2) Mineral analysis

The atomic absorption spectroscopy method was used to determine the potassium, magnesium, iron, zinc, calcium and sodium concentrations of the samples [25].

Total carotenoids

The low volume hexane extraction method (LVHEM) described by Fish et al. [26] was used with slight modification. A weighed amount of samples (1 g) was put in an amber screw-top vial. A measured volume of cold acetone (5 ml), ethanol (5 ml) and hexane (5 ml) were added. The mixture was placed in an ice bath with constant shaking for 30 minutes. Three millilitres of deionized water was added with the mixture still in the ice bath for an additional 5 minutes. The mixture was then left at room temperature for 5 minutes for phase separation. The absorbance of upper hexane layer was read in 1 cm quartz cuvette at 468 nm.

The concentration of the extract was calculated as follows:

C (µg/g sample) = (ΔA X volume of extract X dilution)/ (0.2 X weight of sample used in grams)

3) Vitamin C

Vitamin C was determined by using the indophenol method [27]

4) Amino Acid Profile

A volume of 10 mL of 6 N Hydrochloric acid was added to 2 g of the sample to form a slurry and thoroughly mixed. The slurry was heated for 24 hours at 110 °C. The sample was cooled and centrifuged at 4000 rpm for 5 minutes. The supernatant was then used as the sample solution. Pre-column derivatization was done at room temperature using OPA and FMOC. An aliquot of 200 µL of digested samples was added to 200 µl of 0.4 M borate buffer (pH, 10.2). To the solution, 100 µl of OPA reagent and 15 Mm FMOC-Cl (in acetonitrile) were each added for derivatization to occur. After 5 minutes, 600 µl of distilled water was added and 100 µl injected into a Cecil-Adept Series Binary Pump HPLC (Cecil Instruments, Cambridge, England). The HPLC Conditions were as follows: mobile phase A: 40mM CH3COONa (pH 7.8); mobile phase B: CH3CN: CH3OH: H2O (45:45:10 v/v/v); flow rate: 1 mL/min; column: Phenomenex 3.5 µm, 4.6 mm ID, 15 cm; temperature: 40°C ; detector: Shimadzu 10AxL Fluorescence Detector run time: 60 min wavelength: Ex: 340 nm Em: 450 nm; flow rate: 1 mL/min [28, 29, 30].

5) Water and oil absorption capacity

The water absorption capacity of the powdered mixes was evaluated by placing 2 g samples in centrifuge tubes and adding 40 mL of distilled water. The resultant slurry was shaken for 1 hour and centrifuged at 2200 rpm for 15 minutes. The supernatant was decanted and the amount of water in grams gained by a 100 g sample was determined for the water absorption capacity [31]. The same procedure was carried out using refined vegetable oil (Frytol®) for the oil absorption capacity. The density of water was taken to be 1 gcm^{-3} and the density of oil was taken to be 0.93 gcm^{-3}.

6) Least gelation concentration

The least gelation concentration was determined by the method described by [32]. Suspensions of the powdered mixes at concentrations of 2–20% w/v were prepared in distilled water. Ten millilitres of each prepared suspension were transferred into a test tube. The test tubes were heated in a boiling water bath for 1 hour, cooled rapidly under running water, and further cooled in a refrigerator at 4oC for 2 hours. The least gelation concentration was taken as the concentration at which the sample did not fall from the inverted test tube.

III. RESULTS AND DISCUSSION

A. Nutritional composition of senescent plantain powdered mixes

TABLE 2. MEAN PROXIMATE COMPOSITION OF SENESCENT PLANTAIN FOAM MAT AND POWDERED MIXES

Sample	Moisture (g/100g)	Crude protein (g/100g)	Crude fibre ((g/100g)	Ash (g/100g)	Crude fat (g/100g)	Carbohydrate (g/100g)	Energy (kcal)
EAPF	$10.44^{de} \pm 0.02$	1.59a ± 0.09	0.75a	$2.40^{a} \pm 0.14$	4.44a ± 0.01	$80.39^{c} \pm 0.05$	**367.86a ± 0.4**
EAPFRCF	$10.15^{cd} \pm 0.09$	2.37d ± 0.40	2.33b ± 0.08	$3.01^{bc} \pm 0.48$	8.24c± 0.08	$73.90^{a} \pm 0.17$	**379.24bc ± 3.05**
EAPFSCF	$10.68^{e} \pm 0.08$	1.89b ± 0.03	2.55c ± 0.02	$3.41^{cd} \pm 0.02$	7.54b ± 0.15	$73.94^{a} \pm 0.02$	**371.15a ±1.34**
SPPF	$9.63^{b} \pm 0.13$	2.63e ± 0.08	2.64 cd ± 0.01	$2.75^{ab} \pm 0.01$	8.44c ± 0.28	$73.92^{a} \pm 0.23$	**382.14c ± 1.88**
SPPFRCF	$9.91^{bc} \pm 0.05$	2.02c ± 0.03	2.72d ± 0.02	$3.69^{d} \pm 0.05$	8.41c ± 0.04	$73.27^{a} \pm 0.07$	**376.81b ± 0.49**
SPPFSCF	$9.13^{a} \pm 0.37$	1.87b ± 0.13	3.19e ±0.02	$3.49^{cd} \pm 0.11$	7.61 b ± 0.31	$74.73^{b} \pm 0.73$	**374.84b ± 0.40**

Means followed by different superscript within a column indicate significant difference ($p < 0.05$)

The proximate composition of the foam mat dried senescent plantains EAPF and SPPF and their respective powdered mixes EAPFRCF, EAPFSCF, SPPFRCF and SPPFSCF are presented in Table 2.

The moisture of the samples ranged between 9.10 g/100g and 10.68 g/ 100g for SPPFSCF and EAPFSCF, respectively. The powdered mixes formulated with EAPF had relatively higher moisture content compared to those formulated with SPPF. Generally, there were significant differences among the samples ($p < 0.05$). However, samples SPPFRCF and SPPF did not show any significant difference. Also, the SPPFRCF and EAPFRCF samples did not show any significant difference. Samples EAPFRCF were also statistically similar to samples EAPF and EAPFSCF. The moisture content of food is an indication of its quality and influences its stability. To ensure shelf stability (of at least 6 months), food powders are expected to have moisture contents below 12 g/100g, and the data from this study fall within this range (Kaur et al., 2011). The values obtained are comparable to the moisture contents of wheat flour (10.3 g/100g), enriched, dry macaroni (9.9) [27], soy-plantain flour (ranging from 9.65 to 9.80 g/100g) [33], and taro powder (ranging between 8 to 10 g/100g) [34]. The low moisture contents of the samples are expected to give them a relatively longer shelf life compared to the senescent plantain products, which had higher moisture contents ranging between 47.6 and 64.2 [35].

The protein levels ranged from 1.59 g/100g for EAPF and 2.6 g/100g for SPPF. The variation in the protein contents of the samples may be attributed to differences in the protein contents of the foaming agents used (i.e., egg albumen and soy protein extract). These foaming agents have different protein compositions, except that the egg albumen was in liquid form and the soy protein extract was in powdered form. Additionally, the differences in the formulations could also contribute to the variations in the protein contents of the samples, which were statistically significant ($p < 0.05$). The addition of the foaming agent did not significantly improve the protein content of the powdered mix, as it was added in very minute quantities (6.25%). Crude protein levels of 1.66 g/100g, 2.6 g/100g and 2.2% have been reported for senescent plantain products, overripe plantain and ripe dessert bananas, respectively [20, 35,36].

The crude fibre contents of the samples ranged from 0.75 g/100 g to 3.19 g/100g. Sample EAPF had the lowest crude fibre content, and the SPPFSCF sample had the highest crude fibre content. The variations in the crude fibre content of the samples were statistically significant ($p < 0.05$).

Yusufu et al. (37) recorded a crude fibre content of 2.3 g/100g for enriched Apulia, a roasted maize meal, and Oduro et al. [38] also reported a crude fibre range between 1.47 g/100g and 2.50 g/100g for gari, both of which are within the range of results obtained for the samples. Crude fibre has an important nutritional role in controlling bowel movement, keeping the colon clean, and lowering blood cholesterol [39].

The ash content of the samples reflects the mineral levels in the sample. The variations in the ash contents were significant ($p < 0.05$). Sample EAPF recorded a total ash content of 2.4 g/100 g, while SPPFRCF had the highest total ash content (3.7 g/100g). The ash content of the samples is similar to that of dried fruits, which have been reported to range between 2.4 and 3.5 g/100g [27]. It is also comparable to the ash content of taro powder, which ranges between 1.7 and 2.2 g/100g [35] and ripe apem plantain (2.68 g/100g) [40].

The samples had appreciable amounts of magnesium, potassium, iron and zinc (Figure 2). The differences in the magnesium contents of the samples were not statistically significant ($p > 0.05$). It ranged between 11.2 and 11.4 mg/100g for EAPFSCF and SPPFSCF, respectively. The samples' magnesium levels were lower than those reported for tiger nut wheat cake (83.7–152.46 mg/100g) [41]. Magnesium is a very important mineral that helps in fluid balance, along with sodium, potassium, and calcium, as well as in the transmission of nerve impulses, muscle contraction, and the regulation of the heartbeat [37]. The potassium levels ranged from 7.7 mg/100g to 9.6 mg/100g for SPPFSCF and EAPFSCF, respectively. The potassium contents of EAPFSCF and EAPFSCF were statistically insignificant ($p > 0.05$). The iron composition of the samples was between 1.3 mg/100g and 1.8 mg/100g for SPPPF and EAPFRCF, respectively. The variations in the iron composition for all the samples except SPPF were insignificant ($p > 0.05$). Lower levels of iron (0.56–0.699 mg/100g) and higher magnesium (334–39 mg/100g) have been reported for dockounou (an Ivorian senescent plantain dish) [42]. Since the iron in the samples is non-haem, an acid medium such as

Vitamin C would be needed for proper absorption and utilisation in the body. Zinc is an essential micro mineral for the body's metabolism, functioning of insulin and normal taste acuity [39]. Sample SPPF had the highest zinc content (1.6 mg/100 g), and sample EPPF had the lowest zinc content (0.9 mg/100g). The zinc content reported for dockounou was relatively small (0.19–0.23 mg/100 g) [42]. The differences in the zinc contents could result from differences in the formulations. The calcium contents of the samples were also very high. SPPF had the least Ca content (7.5 mg/200 g), while EAPFSCF had the highest (17.5 mg/100g). The range of calcium values reported for tiger nut wheat cake (54–56 mg/100g) is relatively higher than the samples evaluated [39]. However, reported calcium values for rice bran (5.6–9.5 mg/100 g) [41] were within the range of the results obtained for this study.

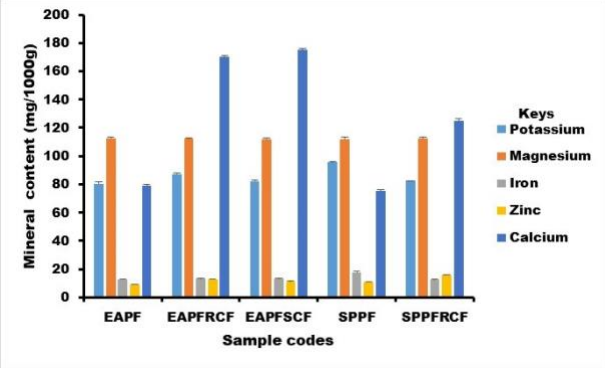

Fig. 2. Mean potassium, magnesium, iron, zinc and calcium contents of the powdered mix samples

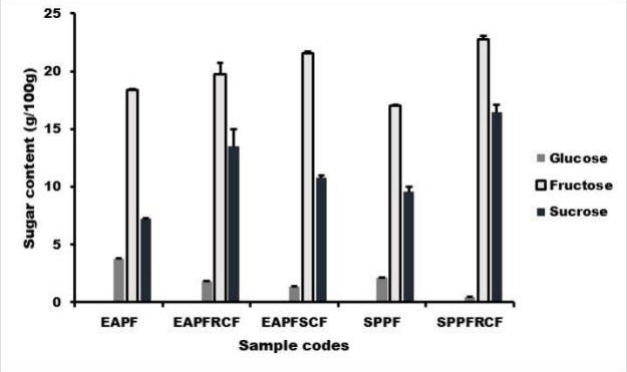

Fig. 3. Mean glucose, fructose and sucrose contents of the powdered mix samples

The variations in the crude fat contents of the samples were statistically significant ($p < 0.05$). Sample EAPF contained the lowest amount of crude fat (4.4 g/100 g), while SPPF had the highest crude fat content (8.44 g/100g). The crude fat contents of the samples are consistent with the range reported for senescent plantain products (0.06 – 9.5 g/100g) [35] and Apula (2.6 – 6 g/100g) [37]. The crude fat content of ofam is expected to increase from the powdered mixes since the formulation requires palm oil. Too high crude fat levels predispose the products to oxidative rancidity during normal room-temperature storage.

The samples were mainly carbohydrates. High carbohydrate values were obtained for the samples, which ranged from 73.3 g/100 g (SPPRCF) to 80.4 g/100g (EAPF). The range recorded is comparable to the total carbohydrate contents of cornflakes (80.4 g/100g), dried enriched macaroni (74.7 g/100 g), and honey (82.4 g/100 g) [27]. The differences in the carbohydrate contents of the samples were statistically significant ($p < 0.05$).

Results indicate that the samples were high in calories, and the difference in the caloric values of the samples was significant ($p < 0.05$). The total energy of sample SPPF was the highest (382.1 kcal), and EPPF recorded the least energy (367.9 kcal). The energy values for EPPF and EPPFSCF were statistically insignificant ($p > 0.05$), as were those for EAPFRCF, SPPFRCF and SPPFSCF. According to Robinson [42], plantains' average total energy value is 128 kcal/100g. The higher values recorded for these samples could be attributed to the ripening stage and the formulation differences.

Since the products contain senescent plantain as the main material, glucose, fructose and sucrose are expected to be the main carbohydrates. Results in figure 3 indicate that the majority of the sugars were fructose, followed by sucrose and then glucose. The glucose content ranged from 0.41 g/100g to 3.73 g/100g for SPPFRCF and EAPF, respectively. The sucrose content of the samples was relatively higher than the glucose content; it ranged between 7.2 g/100g and 16.45 g/100g for EAPF and SPPFSCF, respectively. The fructose content of the samples was generally higher than the values obtained for both glucose and sucrose (Figure 3). The variations in the glucose, sucrose and fructose contents of the samples were significant ($p < 0.05$).

The total carotenoids were highest in the SPPFSC (7.2 µg/g) and lowest in the EAPF (3.4 µg/g) (Figure 4). The variations in the total carotenoids of the samples were significant ($p < 0.05$).

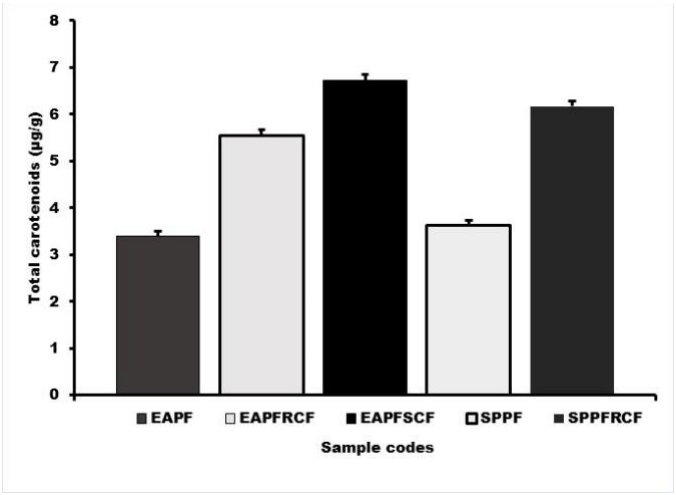

Fig. 4. Mean total carotenoid levels of the powdered mix samples

Vitamin C was also found in appreciable amounts in the samples. It ranged from 17.42 mg/100g to 33.99 mg/100g for EAPF and SPPFSCF, respectively (Figure 5). The variations in Vitamin C were significant ($p < 0.05$). However, differences in EAPF and SPPFSCF were insignificant ($p > 0.05$). The presence of vitamin C is important for the optimal utilisation of the iron present in the samples.

The amino acid concentration of the samples is presented in Table 3. The essential amino acids identified in the samples were histidine, isoleucine, leucine, lysine, methionine, phenylalanine, valine and threonine. Tryptophan was conspicuously missing in the essential amino acids identified. The amount of histidine in the samples was relatively the same, ranging from 0.20 g/100g for samples SPPFSCF, EAPF and EAPFRCF to 0.28 g/100g for the EAPFRCF sample. Sample SPPF recorded the highest value of 0.18 g/100g for isoleucine, followed by EAPF. EAPFSCF was highest in leucine (23 g/100g), and SPPF recorded the highest values for methionine (0.19 g/100 g) and phenylalanine (0.33 g/100g). Aspartic acid was the most abundant non-essential amino acid found in the samples. It ranged from 0.40 g/100g to 0.53 g/100g for samples SPPF and EAPFSCF, respectively. EAPFRCF was highest in glutamic acid (0.25 g/100g) and glycine (0.31 g/100g). Substantial amounts of arginine (0.18 g/100g) and cystine (0.19 g/100g) were also found in SPPF. The values obtained for the various amino acids in this study were higher than those obtained by Ketiku [23] for overripe plantains and Shamla and Nisha [45] for plantain chips fried at stages I, II, III, IV and V ripening. The addition of foaming agents such as egg albumen in EAPF, EAPFRCF and EAPFSCF and soy protein isolates in SPPF, SPPFSCF and SPPFRCF could have increased the concentration of amino acids in the plantain samples and their respective powder mixes, thereby improving protein quality.

B. Water and oil absorption capacity

The water absorption capacity of a material is its ability to be associated with water under limited quantities [44]. The powdered mixes containing roast corn flour (RCF) had a higher water absorption capacity than those containing steeped corn flour (SCF) (Figure 6). EAPFSCF and SPPFSCF had the lowest water absorption capacity (0.82 g/g), while EAPFRCF recorded the highest value (1.10 g/g) (Figure 6). The variation in the water absorption capacity of EAPFRCF and SPPFRCF were not statistically significant ($p > 0.05$). The results indicate that there are more hydrophilic sites in the samples containing RCF, allowing for more water to be absorbed. Mepba et al. [47] reported a water absorption capacity ranging from 1.10 to 1.30 g for wheat/plantain composite flour. Kaur and Singh [48] also reported slightly higher values for chicken peas (1.33 to 1.47 g/g).

EAPFRCF absorbed the least oil (0.84 g/g), while SPPFSCF absorbed the most (0.94 g/g). This implies that EAPFRCF has the least lipophilic tendency. The variations in the oil absorption of the products were statistically insignificant ($p > 0.05$). The samples' ability to bind oil may be similar because they both have a non-polar side that binds the hydrocarbon chains of the oil to the flour. The fat absorption in the powdered mix is useful for flavour retention and improves palatability when used to bake ofam [49]. The results show that EAPFSCF, EAPFRCF, SPPFSCF and SPPFRCF may be lower flavour retainers than tiger nut flour (1.09 to 1.13 g/g) [50], chicken peas (1.05 to 1.24 g/g) [51]. However, the oil absorption capacity for lima beans (0.97 g/g) and lentils (0.93 g/g) [52] was within the value obtained for this study.

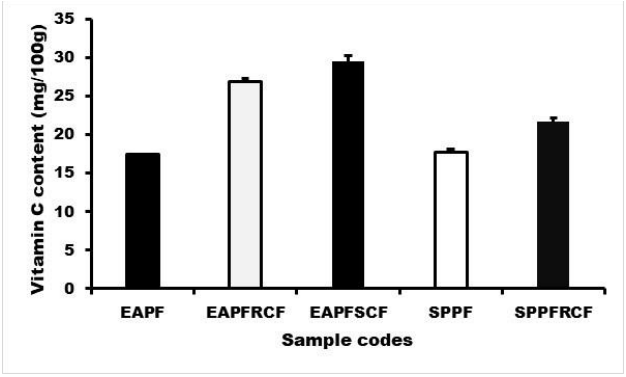

Fig. 5. Mean vitamin C content of the powdered mix samples

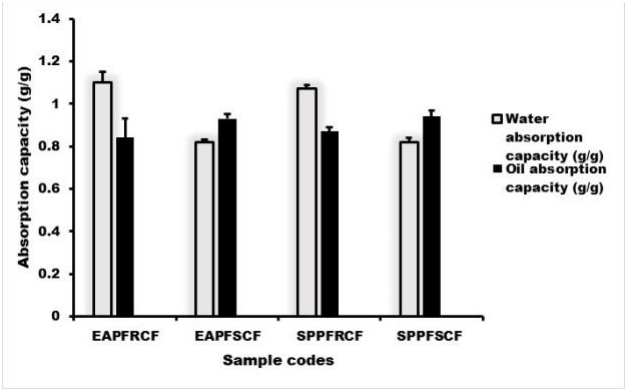

Fig. 6. Mean water and oil absorption capacities of the powdered mix samples

C. Least gelation concentration

This is the minimum amount of flour needed to form a stable gel in 100 mL of water after boiling and cooling. The difference in the gelation capacity of the powdered mix samples was significant ($p < 0.05$). SPPFSCF (22 g/100 mL), which required the least flour to gel, had the best gelation capacity (Figure 7). The difference in the least gelation concentrations of EAPFSCF and SPPFSCF was insignificant ($p < 0.05$).

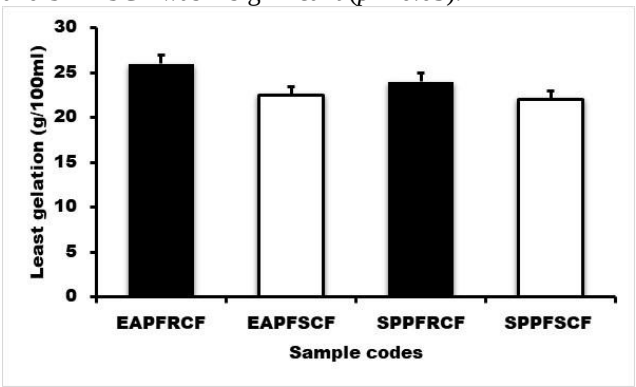

Fig. 7. Mean least gelation of the powdered mix samples

The presence of starch and proteins in the powdered mix is responsible for the gelation. The size of proteins, carbohydrates, and lipids in food suggests the extent of interactions present, hence the gelation property [53]. The least gelation concentration of the samples in this study is higher than

values reported for sesame (16 g/100 mL), rice (18 g/100 mL), wheat (14 g/100 mL) and millet (18 g/100 mL) [54].

IV. Conclusions

The presence of potassium, magnesium, zinc, calcium, total carotenoids, and vitamin C, in addition to the other nutrients present, gives the foam mat dried senescent plantain and powdered mixes the potential for their use in nutritional interventions. The most abundant essential amino acids were phenylalanine, histidine, and methionine, while aspartic acid was the most abundant non-essential amino acid in the samples. Hopefully that the samples with relatively lower moisture content than the fresh overripe plantain will have a relatively longer shelf-life.

Amino acid	SPPF (g/100g)	SPPFSCF (g/100g)	SPPFRCF (g/100g)	EAPF (g/100g)	EAPFSCF (g/100g)	EAPFRCF (g/100g)
Alanine	0.20	0.20	0.20	0.12	-	-
Arginine	0.18	0.13	0.13	0.14	0.10	**0.15**
Cystine	0.19	0.18	0.17	0.12	0.11	**0.10**
Aspartic acid	0.40	0.38	0.38	0.50	0.53	**0.47**
Glutamic acid	0.21	0.19	0.18	0.16	0.15	**0.25**
Glycine	0.10	0.28	0.28	0.09	0.23	**0.31**
Histidine	0.21	0.20	0.20	0.20	0.20	**0.28**
Isoleucine	0.18	0.15	0.14	0.08	0.07	**0.07**
Leucine	0.07	0.12	0.12	0.15	0.23	**0.18**
Lysine	0.07	-	-	0.08	-	-
Methionine	0.19	0.15	0.15	0.03	0.14	**0.20**
Phenylalanine	0.33	0.10	0.10	0.10	0.04	**0.10**
Proline	0.05	-	-	0.11	-	**0.02**
Valine	0.06	-	-	0.09	0.01	**0.03**
Threonine	-	0.05	0.05	-	-	**0.16**
Tyrosine	-	0.02	0.02	0.05	0.03	**0.05**
Serine	-	-		-	0.02	-

References

[1] Adi, D. D. (2024). The role of plantain in promoting food security: A review. Food and Nutrtion Sciences 15: 313-335 DOI: 10.4236/fns.2024.155021

[2] Zhang, P., Whistler, R. L., BeMiller, J. N., and Hamaker, B. R. (2005). Banana starch: production, physicochemical properties, and digestibility—a review. Carbohydrate Polymers 59, 443-458. https://doi.org/10.1016/j.carbpol.2004.10.014

[3] Aurore, G., Parfait, B., and Fahrasmane, L. (2009). Bananas, raw materials for making processed food products. Trends in Food Science & Technology 20, 78-91. https://doi.org/10.1016/j.tifs.2008.10.003

[4] John, P., and Marchal, J. (1995). Ripening and biochemistry of the fruit. In "Bananas and plantains", pp. 434-467. Springer.

[5] Hardisson, A., Rubio, C., Baez, A., Martin, M., Alvarez, R., and Diaz, E. (2001). Mineral composition of the banana (Musa acuminata) from the island of Tenerife. Food Chemistry 73, 153-161. https://doi.org/10.1016/S0308-8146(00)00252-1

[6] Forster, M. P., Rodríguez Rodríguez, E., and Díaz Romero, C. (2002). Differential characteristics in the chemical composition of bananas from Tenerife (Canary Islands) and Ecuador. Journal of Agricultural and Food Chemistry 50, 7586-7592. https://doi.org/10.1021/jf0257796

[7] Izonfuo, W. A. L., and Omuaru, V. O. (1988). Effect of ripening on the chemical composition of plantain peels and pulps (Musa paradisiaca). Journal of the Science of Food and Agriculture 45, 333-336. https://doi.org/10.1002/jsfa.2740450407

[8] Adeyemi, O., and Oladiji, A. (2009). Compositional changes in banana (Musa ssp.) fruits during ripening. African Journal of Biotechnology 8. 853 - 859 t http://www.academicjournals.org/AJB

[9] Chandler, S. (1995). The nutritional value of bananas. In "Bananas and plantains", pp. 468-480. Springer.

[10] Englberger, L., Darnton-Hill, I., Coyne, T., Fitzgerald, M. H., and Marks, G. C. (2003). Carotenoid-rich bananas: a potential food source for alleviating vitamin A deficiency. Food and nutrition bulletin 24, 303-318. https://doi.org/10.1177/156482650302400401

[11] Englberger, L., Schierle, J., Aalbersberg, W., Hofmann, P., Humphries, J., Huang, A., Lorens, A., Levendusky, A., Daniells, J., and Marks, G. C. (2006). Carotenoid and vitamin content of Karat and other Micronesian banana cultivars. International Journal of Food Sciences and Nutrition 57, 399-418. https://doi.org/10.1080/09637480600872010

[12] Pareek, S. (2016). Nutritional and Biochemical Composition of Banana (Musa spp.) Cultivars. In "Nutritional Composition of Fruit Cultivars", pp. 49-81. Elsevier. https://doi.org/10.1016/B978-0-12-408117-8.00003-9

[13] Seymour, G. (1993). Banana. In "Biochemistry of fruit ripening", pp. 83-106. Springer.

[14] Seymour, G. (1984). The effects of gases and temperature on banana ripening, University of Reading.

[15] Inocent, G., Adelaide, D. M., Gisele, E. L., Solange, M. O. R., Richard, E. A., and Elie, F. (2011). Impact of three cooking methods (steaming, roasting on charcoal, and frying) on the β-carotene and vitamin C contents of plantain and sweet potato. Americna Journal of Food Technology 6, 994-1001. http://scialert.net/fulltext/?doi=ajft.2011.994.1001&org=10

[16] Rojas-Gonzalez, J. A., Avallone, S., Brat, P., Trystram, G., and Bohuon, P. (2006). Effect of deep-fat frying on ascorbic acid, carotenoids and potassium contents of plantain cylinders. International Journal of Food Sciences and Nutrition 57, 123-136. https://doi.org/10.1080/09637480600658393

[17] Rickman, J. C., Barrett, D. M., and Bruhn, C. M. (2007). Nutritional comparison of fresh, frozen and canned fruits and vegetables. Part 1. Vitamins C and B and phenolic compounds. Journal of the Science of Food and Agriculture 87, 930-944. https://doi.org/10.1002/jsfa.2825

[18] Davey, M. W., Stals, E., Ngoh-Newilah, G., Tomekpe, K., Lusty, C., Markham, R., Swennen, R., and Keulemans, J. (2007). Sampling strategies and variability in fruit pulp micronutrient contents of West and Central African bananas and plantains (Musa species). Journal of Agricultural and Food Chemistry 55, 2633-2644. https://doi.org/10.1021/jf063119l

[19] Marriott, J., and Lancaster, P. (1983). Bananas and plantains. Handbook of tropical foods, 85-143.

[20] Mohapatra, D., Mishra, S., and Sutar, N. (2010). Banana and its by-product utilisation: an overview. Journal of Scientific & Industrial Research 69, 323-329.

[21] Ketiku, A. O. (1973). Chemical composition of unripe (green) and ripe plantain (Musa paradisiaca). Journal of the Science of Food and Agriculture 24, 703-707. https://doi.org/10.1002/jsfa.2740240610

[22] AOAC (2000). Association of Official Analytical Chemists. Official Methods of Analysis. 17th ed Washington DC USA.

[23] AOAC (2010).Official Methods of Analysis, 20th edition. Association of Official Analytical Chemists, Washington, DC

[24] Osborne, D. R., and Voogt, P. (1978). Calculation of calorific value. The analysis of Nutrients in Foods, Academic Press London, 239-240.

[25] Bader, N. R. (2011). Sample preparation for flame atomic absorption spectroscopy: An Overview. Rasayan Journal of Chemistry 4, 49 - 55.

[26] Fish, W. W., Perkins-Veazie, P., and Collins, J. K. (2002). A quantitative assay for lycopene that utilizes reduced volumes of organic solvents. Journal of Food Composition and Analysis 15, 309 - 317. https://doi.org/10.1006/jfca.2002.1069

[27] Nielsen, S. S. (2010). Food Analysis Laboratory Manual. Springer, New York. pp. 139-141

[28] Bartolomeo, M. P., and Maisano, F. (2006). Validation of a Reversed-Phase HPLC Method for Quatitative Amino Acid Analysis. Journal of Biomolecular Techniques 17, 131 - 137.

[29] Henderson, J. W., Ricker, R. D., Bidlingmeyer, B. A., & Woodward, C. (2000). Rapid, accurate, sensitive, and reproducible HPLC analysis of amino acids. Amino acid analysis using Zorbax Eclipse-AAA columns and the Agilent, 1100(1100), 1-10.

[30] Steed, R. (2010). " Analysis of Amino Acids by HPLC Manual," Agilent Technologies, Inc., USA.

[31] Yamazaki, W. T. (1953). An alkaline water retention capacity test for the evaluation of cookies in baking potentialities of soft winter wheat flours. Cereal Chemistry 30, 242 - 246.

[32] Coffman, C. W., and Garcia, V. V. (1977). Functional properties and amino acid content of protein isolate from mung bean flour. Journal of Food Technology 12, 473 - 484. https://doi.org/10.1111/j.1365-2621.1977.tb00132.x

[33] Abioye, V., Ade-Omowaye, B., Babarinde, G., and Adesigbin, M. (2011). Chemical, physico-chemical and sensory properties of soy-plantain flour. African Journal of Food Science 5, 176-180.

[34] Himeda, M., Njintang, Y. N., Gaiani, C., Nguimbou, R. M., Scher, J., Facho, B., and Mbofung, C. M. (2014). Physicochemical and thermal properties of taro (Colocasia esculenta sp) powders as affected by state of maturity and drying method. Joutrnal of Food Science Technology 51, 1857-65. https://doi.org/10.1007/s13197-012-0697-9

[35] Adi, D. D., Oduro, I., Tortoe, C., Kwofie, E. M., and Simpson, B. K. (2018). Physicochemical characteristics and microbiological quality of senescent plantain products. Cogent Food & Agriculture 4, 1441596. https://doi.org/10.1080/23311932.2018.1441596

[36] Onwuka, G., and Onwuka, N. (2005). The effects of ripening on the functional properties of plantain and plantain based cake. International journal of food properties 8, 347-353. https://www.tandfonline.com/doi/full/10.1081/JFP-200059489

[37] Yusufu, P. A., Egwujeh, S. I. D., Damak, A., and Netala, J. (2014b). Enrichment of 'Apula'-A Roasted Maize Meal with African Yam Bean and Plantain Fruit Flour. Pakistan Journal of Nutrition 13, 377 - 380. http://pjbs.org/pjnonline/fin2765.pdf

[38] Oduro, I., Ellis, W. O., Dziedzoave, N. T., and Nimako-Yeboah, K. (2000). Quality of gari from selected processing zones in Ghana. Food Control 11, 297 - 303. https://doi.org/10.1016/S0956-7135(99)00106-1

[39] Roday, S. (2012). "Food Science and Nutrition " 2nd/Ed. Oxford University Press, New Delhi.

[40] Zakpaa, H. D., Mak-Mensah, E. E., and Adubofour, J. (2010). Production and characterization of flour produced from ripe "apem" plantain (Musa sapientum L. var. paradisiacal; French horn) grown in Ghana. Journal of Agricultural Biotechnology and Sustainable Development 2, 92 - 99.

[41] Chinma, C. E., Abu, J. O., and Abubakar, Y. A. (2010). Effect of tigernut (Cyperus esculentus) flour addition on the quality of wheat-based cake. International Journal of Food Science & Technology 45, 1746-1752. https://doi.org/10.1111/j.1365-2621.2010.02334.x

[42] Severin, K. K., Akoa Essoma, E., Yeboah, D. K., Akpa, E. E., and Niamke, S. L. (2013). Physicochemical and nutritional characteristics assessement of two different traditional foods prepared with senescent plantain. African Journal of Food Science 7, 51-55. http://www.academicjournals.org/ajfs/contents/2013cont/Mar.htm

[43] Amissah, J. G. N., Ellis, W. O., Oduro, I., and Manful, J. T. (2003). Nutrient composition of bran from new rice varieties under study in Ghana. Food Control 14, 21 - 24. https://doi.org/10.1016/S0956-7135(02)00047-6

[44] Robinson, J. (1996). Bananas and plantains, crop production science in horticulture 5. CAB International, Wallingford.

[45] Shamla, L., and Nisha, P. (2017). Acrylamide formation in plantain (Musa paradisiaca) chips influenced by different ripening stages: A correlation study with respect to reducing sugars, amino acids and phenolic content. Food chemistry 222, 53-60. https://doi.org/10.1016/j.foodchem.2016.12.007

[46] Singh, U. (2001). Functional properties of grain legume flours. Journal of Food Science & Technology. 38, 191 - 199.

[47] Mepba, H. D., Eboh, L., and Nwaojigwa, S. U. (2007). Chemical composition, functional and baking properties of wheat-plantain composite flours. African Journal of Food, Agriculture, Nutrition and Development, 7(1). 1-23 https://www.ajol.info/index.php/ajfand/article/view/136129

[48] Kaur, M., and Singh, N. (2005). Studies on functional, thermal and pasting properties of flours from different chickpea (Cicer arietinum L.) cultivars. Food Chemistry 91, 403-411. https://doi.org/10.1016/j.foodchem.2004.06.015

[49] Fennema, O. R. (1996). "Food Chemistry," third ed/Ed. Marcel Dekker, New York.

[50] Oladele, A. K., and Aina, J. O. (2007). Chemical composition and functional properties of flour produced from two varieties of tigernut (Cyperus esculentus). African Journal of Biotechnology, 6(21) 2473-2476 DOI: 10.5897/AJB2007.000-2391

[51] Kaur, M., Kaushal, P., and Sandhu, S. K. (2011). Studies on physicochemical and pasting properties of taro (Colocasia esculenta L.) flour in comparison with a cereal, tuber and legume flour. Journal of Food Science and Technology 50 (1) 94 -100.

[52] Du, S.-k., Jiang, H., Yu, X., and Jane, J.-l. (2014). Physicochemical and functional properties of whole legume flour. LWT-Food Science and Technology 55, 308-313. https://doi.org/10.1016/j.lwt.2013.06.001

[53] Singh, U., Sagar, V. R., Behera, T. K., and Kumar, P. S. (2006). Effect of drying conditions on the quality of dehydrated selected vegetables. J Food Sci Technol 43, 579-582.

[54] Joshi, A. U., Liu, C., and Sathe, S. K. (2015). Functional properties of select seed flours. LWT-Food Science and Technology 60, 325-331. https://doi.org/10.1016/j.lwt.2014.08.038