https://doi.org/10.48048/tis.2022.2893

Effects of Citric Acid and Potassium Metabisulphite Pre-Treatment on the Physical and Biochemical Properties of Dehydrated Amritsagar Banana Powder

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Received: 12 October 2020, Revised: 16 May 2021, Accepted: 12 June 2021

Abstract

There are ongoing efforts and studies to mitigate post-harvest losses of the banana through post-harvest employment and processing. Organic acids play some crucial roles in reducing enzymatic browning, biochemical and microbial activity in the dehydration process. This study was conducted to investigate Amritsagar banana powder prepared from ripe bananas and prove the hypothesis that pre-treatment of banana powder improves the storage condition based on the retention ability in physicochemical properties. Bananas were pre-treated with organic acid solutions (0.5 % citric acid (CA), 0.1 % potassium metabisulfite and a blend of both respectively) for 10 min. We observed 2 physical, 5 chemical and 6 mineral content retention properties over 180 days with 60 days intervals from the beginning. By combining ANOVA with Duncan's New Multiple Range Test (DMRT), we assessed that the blend of 0.5 % CA and 0.1 % potassium metabisulfite secured the highest yield and maximum retention of the physical and mineral properties of the banana powder. This blend also yielded higher protein and carbohydrate but lowered the moisture and ash content. Besides, 0.5 % CA was found excellent in lowering fat content with retain ability. Dehydration was previously considered as an efficacious preservation method for perishable crops like bananas. From the comprehensive assessment, this study concludes that pre-treatment with the blend of 0.5 % CA and 0.1 % potassium metabisulfite increases the efficiency of the dehydration process and also increases the shelf life of banana powder maintaining an appreciable quality.

Keywords: Physico-chemical, Minerals, Atomic Absorption Spectroscopy, Storage, Shelf-life

Introduction

Banana, an important climacteric fruit harvested year-long in humid equatorial zones affecting the global economy [1] deals with more than hundreds of species or hybrids in the genus *Musa* [2]. Bangladesh belongs to the leading 30 banana-producing states led by India, China, Indonesia, Brazil and Ecuador. Despite being one of Bangladesh's highest yielded fruit, the production has never been satisfying because of its low yield comparing other states [3,4]. The Horticulture Research Center of Bangladesh has established 18 cultivars on-farm including *Musa cavendishi*, *M. oranta*, *M. paradisiaca*, *M. sapientum*, *M. sylvestris* and *Musa textilis* [5,6]. Amritsagar, a notable AAA (Triploid) cultivar, is familiar among small-scale and garden farmers [7].

Bananas are rich in starch, sugar and potassium [8] and an excellent source of vitamin A, B_6, C and D [9]. This nutritious fruit is adopted as a staple food in many communities and considered as a dietary supplement worldwide [10]. Ripe bananas contain 60 - 80 % moisture [2], susceptible to have a short shelf life with high post-harvest losses. Each season, one-fifth of the harvested bananas are spoiled and reduced in quality, which hampers the economy [11]. The fruit softens and deteriorates via weight loss during post-harvest handling, shipping and storage [12,13]. Longer shelf life products are achievable by converting bananas into different variants, i.e., jam, chips, flakes, powder and flour, etc. [14].

Dehydration is an effective preservation technique for perishable fruits [15] that facilitates the storability of bananas even under a volatile condition with reduced storage, packaging and shipping cost [9]. The existence of polyphenol oxidase namely Tyrosinase in the banana pulp often increases the enzymatic, biochemical and microbial activities during dehydration [16]. Researchers believe that agricultural produce pre-treated with organic acids before dehydration can inhibit the polyphenol oxidase enzyme and preserve the nature of the product [17,18].

Blanching or chemical pre-treatments before dehydration i.e., acidic, ascorbic, benzoic, citric, fumaric, sorbic, tartaric and ethylenediaminetetraacetic acid [16]; calcium chloride, cysteine [19] and potassium metabisulphite (KMS) [20] are generally recognized as safe for browning inhibition. The use of single or multiple chemicals as a pre-treatment solution varies from product to product. The chemical concentration of the solution depends on its effectiveness during and after processing. Pre-treatments were done not only to achieve higher yield but also for the stability and retention ability of the physicochemical properties throughout the storage period.

Banana has limited information related to its pre-treatments along with the effects during storage. We hypothesized that pre-treatment improves the physiological properties of the banana and increases its shelf life. So, in this study, we tried to examine the effects of CA and KMS pre-treatment on the physical and biochemical properties of dehydrated Amritsagar banana powder during storage.

Materials and methods

Sources of materials

Fresh, non-infected and non-injured ripe Amritsagar banana at stage 5 of ripeness (more yellow than green) [1] was collected from resident cultivars of Dinajpur, Bangladesh. Analytical grade reagents and potable water were used throughout the investigation. Low-density polyethylene bags (0.0508 mm thickness, Nahid Plastic, Gazipur, Bangladesh) were adopted as the packaging material during storage.

Preparation of banana powder

The collected fruits were washed carefully with potable water to remove dirt and surface micro-organisms. Later they were peeled off and chopped into pieces (approx. 2 mm thick) using a sharp stainless steel knife. Banana slices weighing a total of 500 g each were poured separately into the pots having a liter of pre-treatment solutions (**Table 1**).

Table 1 Treatment conditions for fresh Amritsagar banana slices.

Treatments	Solution Specifications
T_0	De-ionized water (Control)
T_1	0.5 % citric acid
T_2	0.1 % potassium metabisulfite
T_3	0.5 % citric acid + 0.1 % potassium metabisulfite

After soaking for 10 min, we allowed treated slices to drain out through a plastic sieve. Dehydration was done using a drying cabinet (Model-136-12, Seoul, Korea) at 60 ± 5 ºC for 24 h. The dried chips were ground into powder by using a heavy-duty grinder (Jaipan CM/L-7360065, Japan). Fine powder (0.3 mm) was achieved by sieving through (Sieve no. MIC- 300) and then packed in low-density polyethylene (LDPE) bags. These bags were sealed and stored at room temperature (21 - 32 ºC) for 6 months. Before the storage period started, several physicochemical quality indicators of the samples were kept noted as day 0. At the interval of 60 days, we observed the same quality indicators for statistical assessment.

Physical studies of banana powder

Water holding capacity (WHC) and oil holding capacity (OHC) were estimated by modifying methods stated by Rodriguez-Ambriz *et al*. [21] and Anyasi *et al*. [16]. For each sample, 1 g of banana powder was mixed with 10 mL of de-ionized water for WHC and 10 mL of commercial soybean oil (Teer, City Edible Oil Ltd., Narayanganj, Bangladesh) was vortexed (KMC-1300V, Vision Scientific Co. Ltd., Daejeon-si, Korea) for OHC. Samples were incubated (BD 56, Binder, Tuttlingen, Germany) at 80 ºC for 10 min and then centrifuged (MF-300, HumanLab Instrument Co., Suwon-city, Korea) at 3,000 rpm for 20 min. The supernatant was decanted and weighed to calculate WHC and OHC.

$$WHC = (m_{wet} - m_{dry}) / m_{dry} \text{ Water } g^{-1}$$

$$OHC = (m_{oiled} - m_{dry}) / m_{dry} \text{ Oil } g^{-1}$$

Where, m_{wet} = weight of wet sample, m_{oiled} = weight of oiled sample, m_{dry} = weight of dry sample.

Biochemical studies of banana powder

We have performed a proximate analysis of chemical and mineral contents using ideal methods. Moisture, ash and protein (nitrogen) contents were determined according to the AOAC official methods 934.06, 923.03 and 920.152 respectively [22]. Crude fat content was measured corresponding to AOCS standard procedure Am 5-04 [23]. The total carbohydrate of the powder was calculated by subtracting technique [24], whereby, % total carbohydrate = 100 % – (moisture + ash + crude protein + crude fat) %. Atomic Absorption Spectrometry (AAS) (Perkin Elmer 3100, Perkin Elmer, Inc, USA) was used to predict Potassium, Calcium, Magnesium, Zinc, Iron and Phosphorus contents according to Hardisson *et al*. [25]. For the study of Potassium, Calcium, Magnesium, Zinc, Iron and Phosphorus contents; 0.5 g dried (105 ± 5 ºC) and then ashed (450 ± 25 ºC) samples were taken and dissolved in acid solutions (perchloric and nitric acid) for digestion. Later lanthanum chloride was used to avoid the interferences in the determination of minerals and the molybdovanadate technique was used for the determination of Phosphorus.

Statistical analysis

The data were organized using Microsoft Excel 2007 (Microsoft Corp., USA), and statistics were obtained by using IBM SPSS Statistics 25 (IBM Corporation, USA). We had carried out the analysis of variance (ANOVA) in triplicates and revealed the results as mean values. DMRT was used to test our hypothesis at significant differences ($p < 0.05$) by comparing the treatments within the storage periods.

Results and discussion

Physical properties

Water holding (WHC) and oil holding capacity (OHC)

WHC deals with the physical state of starch as the fragmentation of native starch granules, dietary fiber, and putrefaction of proteins in the banana flour [26,27], and the results presented in **Table 2**. The WHC of each sample at each period decreased from 0 to 180th days. WHC for samples was in the increasing order as $T_0 < T_2 < T_1 < T_3$. Pre-treatment with CA increased WHC more than KMS but when they were incorporated together, the result was significantly high. Thus, the combination helped to increase the WHC. The values are lower than those mentioned in the dietary fiber of mango and mango peel [28] but similar to those of fiber-rich unripe banana flour [21]. Nguyen *et al*. [29] showed that heating not only denatures protein but also expanded the availability of polar amino groups for hydrogen and water bonding. Besides, the duration of storage also had shown a positive correlation with denaturing and destruction of proteins, and thus reduces WHC [30].

According to Rodriguez-Ambriz *et al*. [21], OHC relates to the hydrophilic nature of starches present in the powder, which could be present in the banana powder. OHC deteriorated over the storage period (**Table 2**). The values were similar to those reported in [28] but lower than [31]. Only the T_3 was found to have better OHC with the best retain ability than the control. A good oil retention capacity of powders makes them suitable in food preparation that involves oil blending, such as bakery products where oil is an active ingredient.

Table 2 WHC and OHC of Amritsagar banana powder during storage.

Parameters	Treatments	Storage Periods			
		0 Day	60 Days	120 Days	180 Days
WHC	T_0	$^{c}2.69 \pm 0.16^{A}$	$^{c}2.55 \pm 0.07^{AB}$	$^{c}2.4 \pm 0.12^{B}$	$^{c}2.11 \pm 0.16^{C}$
	T_1	$^{b}3.11 \pm 0.07^{A}$	$^{b}2.94 \pm 0.08^{B}$	$^{b}2.82 \pm 0.06^{B}$	$^{b}2.54 \pm 0.06^{C}$
	T_2	$^{b}3.00 \pm 0.11^{A}$	$^{bc}2.73 \pm 0.24^{A}$	$^{b}2.75 \pm 0.04^{A}$	$^{c}2.26 \pm 0.16^{B}$
	T_3	$^{a}3.79 \pm 0.01^{A}$	$^{a}3.62 \pm 0.06^{B}$	$^{a}3.55 \pm 0.10^{B}$	$^{a}3.52 \pm 0.06^{B}$
OHC	T_0	$^{b}1.02 \pm 0.02^{A}$	$^{b}0.93 \pm 0.02^{B}$	$^{b}0.87 \pm 0.02^{C}$	$^{c}0.70 \pm 0.02^{D}$
	T_1	$^{c}0.93 \pm 0.03^{A}$	$^{b}0.92 \pm 0.01^{A}$	$^{d}0.79 \pm 0.02^{B}$	$^{d}0.50 \pm 0.02^{C}$
	T_2	$^{b}0.99 \pm 0.01^{A}$	$^{c}0.85 \pm 0.01^{B}$	$^{c}0.84 \pm 0.01^{B}$	$^{b}0.77 \pm 0.02^{C}$
	T_3	$^{a}1.09 \pm 0.01^{A}$	$^{a}1.01 \pm 0.02^{B}$	$^{a}0.94 \pm 0.01^{C}$	$^{a}0.87 \pm 0.03^{D}$

Each value represents the mean of triplicate. Different superscript (a - d) letters indicate statistically significant differences ($p < 0.05$) among samples in the same column. Different superscript (A - D) letters indicate statistically significant differences ($p < 0.05$) among days in the same row.

Biochemical properties

Proximate compositions

Table 3 displays the proximate chemical composition of banana powder. There were significant differences in moisture among the samples and increased with the advancement of the storage period because we packed the samples in low-density polyethylene (LDPE) packets. According to Obadina *et al.* [32], the temperature and relative humidity during transportation and storage can influence that moisture content. Besides, the density of packaging materials also influences the moisture contents during storage as Adebowale *et al.* [33] observed that the products stored in LDPE had gained higher moisture than high-density polyethylene (HDPE). At the beginning of storage, T_3 recorded the lowest moisture content (4.83 ± 0.46 %) while we found the maximum in control sample T_0 (6.46 ± 0.49 %) followed by sample T_1 (5.76 ± 0.49 %) and T_2 (5.39 ± 0.29). But after 180th days, control T_0 recorded the highest moisture (11.24 ± 0.28 %) than pre-treated samples, while minimum in treatment T_3 (7.86 ± 0.05 %) following similar values as Abbas *et al.* [34] and Haslinda *et al.* [35]. The present study found an increasing trend in moisture because the banana powder absorbed moisture from the atmosphere during storage [36] as manual handling and packaging methods could not stop the air entrapment fully in LDPE packs. However, according to these results, the changes in moisture content were still in an acceptable range.

Initially, we determined the maximum 3.21 ± 0.04 % and minimum 2.39 ± 0.05 % ash for control sample T_0 and sample T_3. Meanwhile, on the 180th day of storage T_0 recorded the highest (4.18 ± 0.08 %) and T_3 recorded the least (2.87 ± 0.15 %) ash content. These values are similar to Islam *et al.* [37] but less than Juarez-Garcia *et al.* [38]. As the storage period progressed, ash content increased gradually. The use of mineral-rich hard water during pre-treatment might be the reason behind such increment of some minerals like calcium [39]. Although, some minerals had decreased gradually with the advancement of storage and it was due to the biochemical activities of microorganisms [33].

Fat content was similar in samples throughout the storage period though the control and T_1 showed a slight difference at 60th and 180th days. The observed fat data was higher than Abbas *et al.* [34]. End of the 180th day, the control showed the lowest fat content similar to Selvamani *et al.* [40] and T_3 had the highest fat content, which was lower than Islam *et al.* [37]. The time and interaction with pretreatment solutions may affect the fat content throughout the storage. Fats are rich in unsaturated fatty acids, which are susceptible to oxidation degradation [30]. The enhanced moisture throughout the storage might have created suitable conditions for enzymes like lipase and lipoxidase to cause a subsequent decrease in fat content [41].

The mean protein content of each sample from the beginning to the 180th days ranged between 1.38 - 3.29 %. The present study observed a slight decrease in protein content throughout the storage period.

Table 3 Proximate compositions of Amritsagar banana powder.

Parameters	Treatments	Storage Periods			
		0 Day	60 Days	120 Days	180 Days
Moisture	T_0	$^{a}6.46 \pm 0.49^{D}$	$^{a}8.73 \pm 0.36^{C}$	$^{a}9.65 \pm 0.072^{B}$	$^{a}11.24 \pm 0.28^{A}$
	T_1	$^{ab}5.76 \pm 0.24^{D}$	$^{b}7.98 \pm 0.33^{C}$	$^{b}8.67 \pm 0.04^{B}$	$^{b}10.46 \pm 0.14^{A}$
	T_2	$^{bc}5.39 \pm 0.29^{D}$	$^{a}8.54 \pm 0.21^{C}$	$^{c}9.23 \pm 0.13^{B}$	$^{a}10.95 \pm 0.06^{A}$
	T_3	$^{c}4.83 \pm 0.46^{D}$	$^{c}5.40 \pm 0.14^{C}$	$^{d}7.017 \pm 0.9^{B}$	$^{c}7.86 \pm 0.05^{A}$
Ash	T_0	$^{a}3.21 \pm 0.04^{D}$	$^{a}3.34 \pm 0.04^{C}$	$^{a}3.69 \pm 0.02^{B}$	$^{a}4.18 \pm 0.08^{A}$
	T_1	$^{c}2.53 \pm 0.04^{D}$	$^{c}2.73 \pm 0.03^{C}$	$^{b}3.08 \pm 0.02^{B}$	$^{b}3.78 \pm 0.08^{A}$
	T_2	$^{b}2.90 \pm 0.04^{C}$	$^{b}3.0 \pm 0.02^{C}$	$^{a}3.62 \pm 0.05^{B}$	$^{a}4.24 \pm 0.14^{A}$
	T_3	$^{d}2.39 \pm 0.05^{C}$	$^{d}2.45 \pm 0.01^{C}$	$^{c}2.62 \pm 0.072^{B}$	$^{c}2.87 \pm 0.15^{A}$
Fat	T_0	$^{a}0.77 \pm 0.30^{A}$	$^{a}0.72 \pm 0.09^{A}$	$^{b}0.48 \pm 0.03^{B}$	$^{b}0.42 \pm 0.13^{B}$
	T_1	$^{b}0.68 \pm 0.02^{A}$	$^{a}0.66 \pm 0.04^{A}$	$^{a}0.66 \pm 0.05^{A}$	$^{a}0.65 \pm 0.06^{A}$
	T_2	$^{a}0.79 \pm 0.05^{A}$	$^{a}0.78 \pm 0.07^{A}$	$^{a}0.63 \pm 0.05^{B}$	$^{ab}0.52 \pm 0.09^{B}$
	T_3	$^{a}0.76 \pm 0.15^{A}$	$^{a}0.70 \pm 0.06^{AB}$	$^{a}0.68 \pm 0.04^{AB}$	$^{a}0.64 \pm 0.04^{B}$
Protein	T_0	$^{c}2.75 \pm 0.06^{A}$	$^{d}2.44 \pm 0.07^{B}$	$^{d}2.03 \pm 0.045^{C}$	$^{c}1.38 \pm 0.06^{D}$
	T_1	$^{c}2.77 \pm 0.04^{A}$	$^{c}2.60 \pm 0.05^{B}$	$^{c}2.24 \pm 0.06^{C}$	$^{bc}1.59 \pm 0.06^{D}$
	T_2	$^{b}3.13 \pm 0.06^{A}$	$^{b}2.91 \pm 0.085^{A}$	$^{b}2.38 \pm 0.049^{B}$	$^{b}1.75 \pm 0.26^{C}$
	T_3	$^{a}3.29 \pm 0.09^{A}$	$^{a}3.15 \pm 0.057^{A}$	$^{a}2.97 \pm 0.055^{B}$	$^{a}2.98 \pm 0.19^{B}$
Carbohydrate	T_0	$^{c}87.74 \pm 0.58^{A}$	$^{b}85.07 \pm 0.90^{B}$	$^{b}85.31 \pm 1.17^{B}$	$^{c}82.88 \pm 0.12^{C}$
	T_1	$^{b}88.62 \pm 0.33^{A}$	$^{b}85.65 \pm 0.7^{B}$	$^{ab}85.99 \pm 0.78^{B}$	$^{b}84.27 \pm 0.63^{C}$
	T_2	$^{bc}88.22 \pm 0.07^{A}$	$^{b}85.50 \pm 0.5^{B}$	$^{b}85.31 \pm 0.88^{B}$	$^{bc}83.16 \pm 0.44^{C}$
	T_3	$^{a}89.82 \pm 0.33^{A}$	$^{a}89.15 \pm 0.8^{A}$	$^{a}87.29 \pm 0.62^{B}$	$^{a}86.92 \pm 0.93^{B}$

Each value represents the mean of triplicate. Different superscript (a - d) letters indicate statistically significant differences ($p < 0.05$) among samples in the same column. Different superscript (A - D) letters indicate statistically significant differences ($p < 0.05$) among days in the same row.

Assigning to Duncan's multiple range tests, we found time and pretreatment had affected protein content at a significant level. After 180^{th} days, sample T_0 has the lowest protein content similar to Selvamani *et al*. [40] and sample T_3 has the highest protein content near about Islam *et al*. [37]. During the storage period, some amino acids were destroyed [30], therefore leading to a decrease in protein content, which accepts the present study.

Since we know ripe banana contains a high level of sugar, starch, and dietary fibers [21]. Total carbohydrate content for pre-treated samples was higher than the control samples as pre-treated solutions can break down the cell wall and enhance the yield of sugars [42]. The values are higher than Abbas *et al*. [34] and Haslinda *et al*. [35]. During the whole storage period of this evaluation, total carbohydrate content was decreased which may be associated with the increasing moisture content attributed to the rapid growth of microorganisms, whose metabolic activities lead to the production of enzymes (such as proteases and amylases) that catalyzes biochemical reactions and breakdown the nutrients present in food [33].

Mineral contents

Out of the 6 minerals tested, potassium (K) recorded the highest followed by magnesium (Mg), phosphorus (P), calcium (Ca), iron (Fe), and zinc (Zn) (**Figure 1**). The total ash was estimated by combustion method where the mineral contents were analyzed by AAS resulting in confliction between them. A possible explanation could be the acid digestion used during the AAS assessment, which might have unconfined the bound minerals.

Potassium (K)

The potassium content for all samples was 324.89 - 325.59 mg/100 g of the dry sample at the initial storage. Our reported data was lower than Abbas *et al*. [34] for *Musa Cavendish* variety, with 0.5 % KMS pretreatment, and Haslinda *et al*. [35]. **Figure 1**(**a**) shows that K was the most abundant mineral in the powder, while other minerals were present in a fair amount. It was expected since K occurs in abundance in fruits such as bananas, and any vegetable products [25]. Moreover, our results showed that Potassium content was gradually decreased ($p > 0.05$) during the whole storage period for T_0 followed by T_1 than other treatments. This might be attributed to the temperature of the environment during the storage period, which enhanced the biochemical activities of microorganisms [33]. However, the present study found that the use of chemical pre-treatments did not influence the ash and potassium contents throughout storage. This might be due to the fact that additives like KMS and CA have checked the potassium content.

Calcium (Ca)

Calcium-rich products are particularly good for bones, useful in the prevention of osteoporosis and fractures [43]. According to numerical evaluation, all pre-treated samples have relatively ($p < 0.05$) higher calcium content than the control sample. Moreover, the calcium content of each sample from 0 to 180th days raised moderately (**Figure 1**(**b**)) in parallel to ash content while the storage period progressed. Hurrell [44] reported that decreasing phytate content increases the bioavailability of other minerals because it bears a strong binding affinity with minerals like calcium. Therefore, the calcium content had increased in the advancement of storage periods.

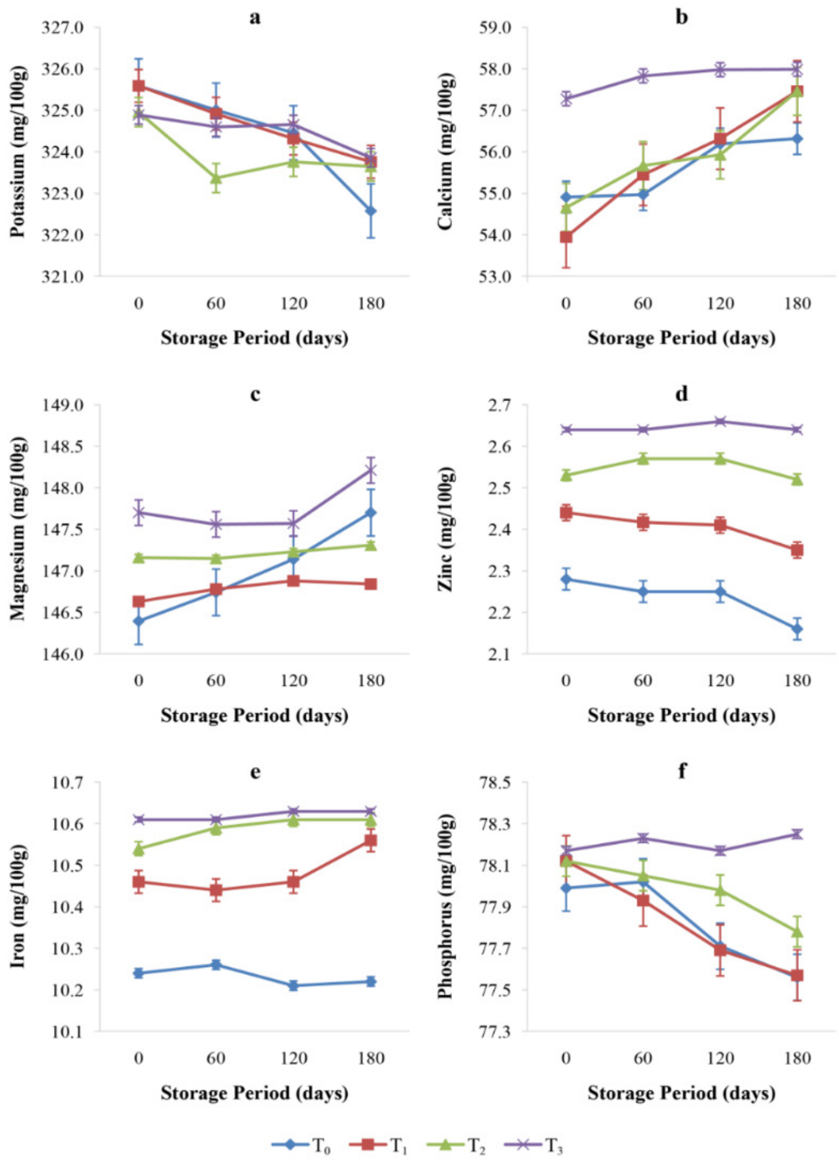

Figure 1 Effects of the pretreatments [(T_0) De-ionized water, (T_1) 0.5 % CA, (T_2) 0.1 % potassium metabisulfite, (T_3) 0.5 % CA + 0.1 % potassium metabisulfite] on mineral contents [(a) Potasium, (b) Calcium, (c) Magnesium, (d) Zinc, (e) Iron, (f) Phosphorus] of Amritsagar banana powder during storage of 180 days.

Magnesium (Mg)

The magnesium content of the control sample was found lower than the pre-treated samples and the highest value of Mg was noted in T_3 (**Figure 1(c)**), which expresses enhanced bioavailability of magnesium of pre-treated banana powder for the reduction of phytate activity and its active binding affinity with minerals like calcium, magnesium, iron, and zinc which makes them unavailable [44]. The reported data of T_2 was higher than Abbas *et al*. [34] with 0.5 % KMS pretreatment and Haslinda *et al*. [35]. The study also interpreted that Mg content was not considerably changed throughout the storage for all samples. At the 180th day of storage, control T_0 recorded the lowest; whereas T_3 recorded the maximum Mg content.

Zinc (Zn)

From the estimated minerals, zinc was found lower than other minerals. Results revealed that there were significant ($p < 0.05$) differences in zinc content among the samples and observed in the order as $T_3 > T_2 > T_1 > T_0$ (**Figure 1(d)**). Zn content was decreased gradually in the advancement of the storage period in all treatments. The obtained values were higher than Abbas *et al*. [34] and Haslinda *et al*. [35]. This indicates that the zinc content of different samples of banana powder was not equally acceptable.

It is quite understandable that pretreatments increased the bioavailability of Zn content of the banana powder. The presence of large quantities of other minerals may also reduce the bioavailability of minerals in food as phosphate, for instance, has been reported to diminish the absorption of Zn [45] but using pre-treated solutions might increase the bioavailability of zinc content of banana powder, which is in close agreement with Hurrell [44].

Iron (Fe)

In this investigation from the obtained values, T_3 secured the highest iron content than other samples and sample T_0 has the lowest value. All the values were higher than Abbas *et al*. [34] and also observed that pretreated samples had higher Fe content than the control sample throughout the storage (**Figure 1(e)**). This trend accepts the results given by Hurrell [44].

Phosphorus (P)

The present research shows that treatment T_3 followed by T_2 has significantly higher phosphorus content than other samples (**Figure 1(f)**). During storage of banana powder, the phosphorus content of all samples gradually decreased except sample T_3. As phytate consists of a larger portion of phosphorus [46] decreasing phosphorus might decrease phytate content resulting in the bioavailability of other minerals [44]. It can be explained that both combination of CA acid and KMS might hinder the bioavailability of phosphorous molecules than other samples. With the advancement of storage, a decreasing pattern in phosphorus content was observed in banana powder, which might be due to the hygroscopic nature of the banana powder capturing some amount of moisture while handling [47].

Conclusions

Dehydration and transformation of bananas into banana powder is an excellent way to reduce its post-harvest losses. Both CA and KMS showed promising results during observation. Their efficacy had increased when they were mixed. Their blend not only retained WHC and OHC, protein, carbohydrate, and mineral contents but also helped to achieve higher yields. The blended solution also lowered the moisture and ash content, but at the same time maintained their retention as well. Though the ash and mineral content we observed during the study challenges their method of testing but this opens a new area of focus for future research. The nutritional potentiality, physical and biochemical properties of banana powder make it reasonable that banana samples pre-treated with 0.5 % CA and 0.1 % potassium metabisulfite solution would be an excellent choice for industrial pre-treatment of banana.

Acknowledgements

The authors would like to acknowledge all of our allies. This research was financially aided by the Institute of Research and Training; and facilitated with laboratory resources by the Department of Food Processing and Preservation, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh.

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