Journal of Scientific Research & Reports
5(1): 47-57, 2015; Article no.JSRR.2015.073
ISSN: 2320-0227

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Biochemical Properties and Nutrient Composition of Some Indigenous Tropical Fruits as Affected by Coating/Waxing Preservation

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JSRR/2015/11204
Editor(s):
(1) Lesław Juszczak, University of Agriculture in Krakow, Poland.
Reviewers:
(1) Anonymous, Gombe State University, Nigeria.
(2) Anonymous, University of Milan, via Celoria 2, 20133 Milano, Italy.
(3) Anonymous, Universidade do Estado de Santa Catarina, Brazil.
Complete Peer review History: http://www.sciencedomain.org/review-history.php?iid=747&id=22&aid=7189

Original Research Article

Received 2nd May 2014
Accepted 12th September 2014
Published 15th December 2014

ABSTRACT

The fruits of avocado (local variety), banana (giant cavendish), cashew (yellow skin variety), mango (Julie variety) and sweet orange (improved variety) at firm ripe stage were obtained, preserved by waxing method and storage effects on biochemical properties, reducing sugar, vitamin C and soluble solid contents investigated. Four different edible fats/oils (animal fat – ANF, Bleached palm oil – BPO, sheabutter – SHB and vegetable oil – VGO) were separately used to wax each fruit commodity in triplicates, including uncoated fruits in storage and fresh samples as control. Then, samples were packaged in perforated plastic baskets, kept in storage at tropical ambient conditions for seven days. After storage moisture, vitamin C, sugar contents, hydrogen ion concentration (pH) and total titratable acidity (TTA) values determined. Moisture losses of 5.3±0.41; 14.7±1.1, 6.2±0.5, 6.7±0.3 and 45.1±1.0% in avocado, banana, mango, sweet orange and cashew apple respectively were recorded by using ANF, SHB and VGO edible fats/oils. On the other hand, moisture losses in the respective uncoated fruits were 22.9±1.9; 23.2±0.9; 66.2±1.5; 9.1±0.3 and 12.7±0.2%. The moisture content loss was based on the original moisture of the fresh fruits. TTA generally reduced among all the preserved fruits regardless of fat/oil used for coating (avocado, 0.010 to 0.014;

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banana, 0.018 to 0.024; mango, 0.018 to 0.030 and sweet orange 0.016 to 0.039 mg citric/100g) which showed evidence of further ripening during storage. There was also reduction in pH values of fruits which varied among edible fats/oils. The pH values for avocado, banana, mango and sweet orange reduced from 5.94 to 4.05; 5.36 to 4.25; 5.12 to 3.30 and 4.90 to 3.52 respectively. SHB and BPO contributed the least reduction in most of the fruits, showing no significant difference ($p \leq 0.05$) between fresh, ripe fruit before storage. Apparently, reduction in total soluble solid and reducing sugar contents of fruit followed the same pattern, while BPO, SHB and VGO contributed the least reduction in banana, mango and sweet orange. Most vitamin C contents 0.084-0.242 mg/100g pulp (65.0-87.5%) were retained in sweet orange, avocado, banana and mango with SHB and BPO. Sheabutter and vegetable oil were found most suitable edible fat/oil as coating agent for retention of moisture, vitamin C, soluble solids and preservation of freshness of ripe banana, sweet orange, avocado and mango for the purpose of shelf - life extension to prevent spoilage during distribution prior to consumption.

Keywords: Tropical fruits; waxing preservation; biochemical/nutrient properties; edible fats/oils.

1. INTRODUCTION

Preservation of raw fruits to maintain freshness, nutrients, excellent eating qualities, extend shelf life and prevent post-harvest losses necessitates fruit storage [1]. Such preservation techniques include traditional on – the – tree storage, controlled and modified atmosphere, hypobaric, gas storage, irradiation and coating (Waxing). Generally, preservation helps to extend shelf life of seasonal fruits (mango, citrus, cashew, banana, apple and many others that are indigenous to Nigeria), thereby making them available all year round and preventing both quantitative and qualitative losses. It also allows duration for marketing and distribution/ transportation without losing nutritional values and freshness. For instance, the essential micronutrients (Vitamins, minerals), natural soluble sugars (from ripened fruits) and water of preserved fruits are utilized for human nutrition.

A typical simple preservation technique is fruit coating (waxing). It is the art of coating fruits with suitably formulated synthetic wax (such as paraffin, carnauba, vegetable wax, shield brits, AP40, wax and combinations) and other agents (including natural edible fats, oils) to prevent moisture loss, shrinkage, reduce respiration rate, provide protection against decay [2]. Apparently, ineffective coating has been reported to result into anaerobic fermentation. If insufficient oxygen is available for respiration due to coating, then respiration rate is reduced but not completely stopped. The use of different natural edible fats/oils has been investigated in this work to preserve some ripened tropical fruits indigenous to Nigeria, and chemical quality evaluation of the preserved fruits is reported.

2. MATERIALS AND METHODS

2.1 Materials used and Sources

Firm ripe, fresh cashew apple – *Anaecardium occidentale* (Brazilian jumbo variety), mango – *Mangifera indica* (Ankpa variety), Banana – *Musa dumenterium* (Giant Cavendish Variety), sweet orange – *Citrullis sp* (Local variety) and Avocado pear (Local variety) were obtained from Anyigba and Ankpa markets, Kogi State of Nigeria. Natural waxing agents (fats/oils) such as: Sheabutter (coded SHB), Bleached palm oil (BPO), Soy vegetable oil (VGO) and Animal fat (ANF) were obtained as pure unadulterated products from reputable supermarkets in Anyigba.

2.2 Fruit Sample Preparation, Coating and Storage

Sizeable quantity (15 pieces of each of cashew apple, sweet orange, Avocado, mango and Banana were immersed in 0.10% Benlate solution (fungicide) for 5 minutes and drained. Then sub-divided each fruit commodity into 5 groups (in triplicate), such that each group contained mixture of the five fruits in a plastic tray with perforations, kept inside aerated laboratory under tropical conditions (28±2ºC and 71% RH). The fruits in each group in 4 separate groups were coated using soft brush as described [3] with sheabutter, bleached palm oil, soy vegetable oil and animal fat respectively. On the other hand, fruits in the 5^{th} group were uncoated as control experiment. The wax formed thin layer (about 0.15 mm) on the fruit peel. Experiment was carried out in triplicates, while storage lasted for seven days. Then after, fruit

samples from each group were washed using detergent solution followed by rinsing in clean water, wiped dry, weighed and used for analysis (moisture content, total soluble solids, pH of fruit pulp, total titratable acidity, reducing sugars, and vitamin C determination). Similar fresh fruit samples (not under storage) were obtained and analysed the same way for the purpose of comparison.

2.3 Chemical Analysis Procedures

2.3.1 Moisture content (db) determination

Moisture content of fruits (dry weight basis) in each experiment before and after storage was determined according to standard method described [4]. Triplicate values obtained were subjected to analysis by determining standard error of the means (SEM).

2.3.2 Reducing sugar content determination

The Nelson Sormogyi method as described [5] was modified and used. 0.2 g sample of fruit pulp was weighed (mettler, toledo PB3002-5) and then sugar content extracted with hot 80% ethanol twice (20 mL each time). The supernatant was evaporated on a water bath at 80ºC. Then 20mL distilled water was added to dissolve the sugar. Aliquots 0.2ml was pipetted to five separate test tubes. Then 10mg/L solution of glucose was prepared as stock solution and also pipetted 0.2, 0.4, 0.6, 0.8 and 1.0 mL into a series of test tubes. The volumes of both samples and standard tubes were made up to 2 mL with distilled water (2 ml water was prepared as blank). To each tube was added 1 mL alkaline copper tartarate reagent, and 1ml arsenomolydalic acid reagent added. The volume in each tubes was made up to 10mL with distilled water, followed by reading the absorbance of blue colour at 620 nm after 10 minutes, using colorimeter (Camspec M106 spectrophotometer). Then the graph of absorbance against concentration (mg glucose/mL solution) plotted. The plot was used to evaluate the amount of reducing sugars present in the samples by interpolation.

2.3.3 Determination of soluble solids content (% Brix)

The total soluble solids (% Brix) of fruit sample before and after storage were determined using hand held brix refractometer (RHB-32 model, Japan) as described [5]. Reading for each sample was taken in triplicates.

2.3.4 Determination of Titratable Acidity (TTA)

The method of using phenolphthalein indicator as described [6] was used to determine titratable acidity in fruit flesh before and after storage. Acidity in cashew, mango and sweet orange were expressed as mg citric acid/100 g sample, and both banana and avocado as mg malic acid/100g sample. Values were obtained in triplicates.

2.3.5 Measurement of the pH of fruit flesh juices

The pH of fruit flesh before and after storage was determined according to method described [4]. 10 g sample of fruit puree was mixed thoroughly with 100 mL distilled water (in warring blender) to form 10% suspension (W/V). Then hydrogen ion concentration as pH of 20mL suspension in small beaker was measured using uniscope pH meter (Model PHS–3B, England). The pH electrode was washed with distilled water, then placed in the suspension, allowed to stabilize, then pH value was recorded. Three determinations were made for each sample.

2.3.6 Ascorbic acid content determination

The method of titration described [7] was used to determine ascorbic acid content of fruits in each experiment before and after storage. Working standard solution of ascorbic acid was prepared (100 mg Ascorbic acid in 100 mL of 4% oxalic acid solution in a standard flask i.e. mg/mL). About 5mL working standard solution was pipetted into a 100 mL conical flask and then titrated against dye solution (V_1mL) containing 2, 6 dichorophenol indophenol which oxidized ascorbic acid.

Appearance of pink colour marked the end point. Amount of dye consumed is equivalent to the amount of ascorbic acid. Five (5) gram fruit flesh was extracted with 100mL of 4% oxalic acid, then centrifuged (100 rpm). Then 5ml of supernatant was pipetted out, 10mL of 4% oxalic acid added and then titrated against the dye solution to obtain titre V_2ml.

2.4 CALCULATION

Ascorbic acid (mg/100 g fruit flesh)

$$= \frac{0.5\text{mg} \times V_2 \times 100\text{ml} \times 100}{V_1\text{ml} \times 5\text{ml} \times 5\text{g (wt. of sample)}}$$

3. RESULTS AND DISCUSSION

3.1 Moisture Content of Preserved Fruits as Affected by Coating/waxing with Edible Fats/Oils

Table 1 shows the moisture content (dry basis) of fat/oil coated fruits before and after storage for seven days under tropical ambient conditions (28±2ºC,71% RH).

Avocado had moisture content of 76.0%, 79.1%, 83.1%, 77.5% with ANF, BPO, SHB and VGO coating agents respectively. While fresh avocado fruit before storage had 88.4% moisture content which was not significantly different ($p \leq 0.05$) from coated samples. On the other hand, uncoated avocado stored for seven days had 65.5% moisture content which was found to be significantly different ($p \leq 0.05$) from the coated and fresh samples of avocado. Results showed that the four edible fats/oils used prevented moisture loss.

Apparently, SHB had most tendency to prevent loss of moisture resulting into weight loss of not more than 5% which made avocado to retain its freshness after storage. Banana had moisture content of 60.3%, 53.0%, 58.4%, 56.8% with ANF, BPO, SHB and VGO respectively. While uncoated banana in storage and fresh ripe banana not kept under storage had 51.9% and 75.1% moisture contents respectively. There was significant difference ($p \leq 0.05$) in moisture content of coated fruits stored and fresh banana. Moisture losses of 15–22% were recorded. Also, cashew apple had moisture content of 58.8%, 53.9%, 47.6%, 32.2% with ANF, BPO, SHB and VGO respectively. Uncoated cashew had 25.9% and fresh cashew 92.1% moisture. It was found that, coated cashew lost moisture ranging from 33.3–60.2% when compared with the fresh fruits. None of the coating agents is therefore suitable for cashew. Again, coated mango with ANF, BPO, SHB and VGO had moisture contents of 69.2%, 63.3%, 68.5% and 64.8% respectively. Also, uncoated mango had 66.2% and fresh mango 75.3% moistures. This showed that the moisture of ANF, SHB coated mango, uncoated and fresh mango were similar. Sweet orange had moisture contents of 73.7%, 68.9%, 70.6%, 69.5%, 66.4$ and 79.1% ANF, BPO, SHB, VGO samples, uncoated and fresh samples respectively. There was no significant difference ($p \leq 0.05$) in moisture contents of the sweet orange samples. Therefore, ANF, SHB, VGO and BPO are suitable coating agents for sweet orange, since moisture loss is less than 10% when compared with the fresh orange. In general, the results showed that both ANF and SHB coating agents could prevent moisture loss below 10% in avocado, mango and sweet orange, and BPO prevented similar loss only in avocado. High viscosity property of both ANF and SHB is responsible for their ability to prevent moisture loss in which case, they are able to seal or block the cell pores of the fruits (i.e. stomata) better than BPO, and VGO; also mostly reduced respiration rate. Again, avocado, mango and sweet orange had very thick peel which could also serve as barrier to prevent moisture loss. The use of Brit AP40 as wax for preserving grape and orange fruits for 12 days with not more than 15% moisture loss has been reported [2] showing that natural SHB and ANF could prevent moisture loss of less than 10% in avocado, mango and orange and could perform better than Brit AP40 wax.

3.2 Effect of Edible Fats/Oil as Coating Agents on Reducing Sugars and Total Soluble Solid Contents of Preserved Fruits

Table 2 shows the reducing sugar content (%) of preserved fruits. Reducing sugars of avocado coated and stored was 0.00%; banana 5.72–8.00%; mango 4.26–5.15%, sweet orange 4.56–5.14% and cashew (no value recorded for cashew due to complete deterioration). There was general reduction in each case of coating agent used, in comparison with the control (fresh fruit samples). While bleached palm oil (BPO) and vegetable oil (VGO) were found to have prevented the least reduction (1.2-1.35%) of reducing sugars in all the fruits, except avocado and cashew, which showed that sugar fermentation was negligible during storage. Similar observation of no fermentation of orange coated with commercial wax was reported by [8]. Table 3 shows the total soluble solid contents of waxed fruits under ambient storage. Reduction in soluble solids followed the same pattern as reducing sugars. Both BPO and ANF showed highest potential to prevent loss of soluble solid in ripe fruits due to biochemical changes during storage for seven days.

3.3 Vitamin C Content of Fruits in Storage as Affected by Fat/Oil Wax

Fig. 1 shows the vitamin C contents of fruits (sweet orange, cashew, mango, banana and avocado) coated with edible fats/oils. Fresh sweet orange, cashew mango; banana and

avocado had vitamin C contents of 0.322, 0.132, 0.088, 0.086 and 0.040 mg/100g respectively. After storage for 7 days, sweet orange fruits coated with ANF, BPO, SHB, VGO and uncoated had vitamin C contents of 0.040, 0.084, 0.240, 0.040 and 0.170 mg/100 g sample respectively. This showed that only SHB preserved greater quantity of vitamin C than the uncoated control sample. Only BPO helped to preserve vitamin C in cashew apple, while vitamin C in cashew coated with other fats/oils could not be determined due to deterioration. For mango, only ANF preserved its vitamin C with over 50% retention. Ironically, uncoated mango had about 95% vitamin C retention. Both BPO and VGO helped to preserve more than 50% of vitamin C in banana (>0.044 mg/100g); and others less than 50%. Only BPO and SHB were found to retain greater vitamin C in Avocado than the control. Based on the effectiveness of each fat/oil to help preserve vitamin C in the fruits, SHB is found suitable for sweet orange and avocado; BPO for cashew, banana and avocado.

Generally, vitamin C loss in ripe fruits is due to natural oxidation, influenced by respiration rate and deterioration. This was manifested in the samples that were not coated with any edible fat/oil. Apparently, both BPO and SHB prevented vitamin C loss in avocado, SHB in sweet orange and BPO in banana. It could be explained that they contain traces of antioxidant against vitamin C destruction unlike VGO and ANF. Similar loss of vitamin C in passion and citrus fruits preserved with commercial wax in combination with fungicidal wash has been reported [8].

3.4 Changes of pH and Titratable Acidity Values of Waxed Fruits during Storage

Fig. 2 and Table 4 show respectively the pH values expressed in terms of hydrogen ion concentration and acidity (as citric) of coated fruits kept in storage at the tropical ambient (28±20c, 70% RH) for 7 days. The pH of stored avocado ranged from 4.05–4.70; cashew 4.41; sweet orange 3.33–4.90, mango 3.30–5.12 and banana 3.43–5.36. It showed decrease in each case of edible fat/oil used as compared with fresh fruits. It is found that the pH values fell within acceptable range for ripe fruits according to codex alimentarious [9]. According to reports by researchers [10], the flavours of waxed sweet orange, mango and avocado after storage were unaffected significantly ($p \leq 0.05$) as revealed by sensory assessment, also showing that there was little or no *in situ* fermentation.

Table 1. Percent moisture content (dry basis) of fat/oil coated fruits under storage (28±2°C, 71% RH) for 7 days

Coating agent	Ripened fruit samples				
	Avocado	**Banana**	**Cashew**	**Mango**	**Sweet orange**
Animal fat (ANF)	76.0[a] (0.01)	60.3[b] (0.07)	58.8[d] (0.08)	69.2[h]	73.7 (0.06)
Bleached palm oil (BPO)	79.1[a] (0.11)	53.0[b] (0.18)	39.3[d] (0.04)	63.3[d] (0.04)	68.9 (0.01)
Sheabutter (SHB)	83.1[a] (0.02)	58.4[b] (0.11)	47.6[d] (0.02)	68.5[h] (0.12)	70.6 (0.01)
Vegetable oil (pure soya oil) (VGO)	77.5[a] (0.04)	56.8[b] (0.05)	32.2[e] (0.07)	64.9[g] (0.01)	69.5 (0.02)
Uncoated fruit	65.5[b] (0.03)	51.9[b] (0.02)	25.9[e] (0.01)	66.2[h] (0.03)	66.4 (0.06)
Fresh fruit (Before storage)	88.4[a] (0.02)	75.1c (0.03)	92.1[f] (0.03)	75.3[h] (0.05)	79.1 (0.01)

Values represent average of 3 determinations (± SEM); Values in a column with the same superscript letter are not significantly different ($p \leq 0.05$)

Table 2. Reducing sugar contents (%) of fat/oil coated fruits under storage (at 28±2ºC) for 7 days

Coating agent	Ripened fruit samples				
	Avocado pear	Banana	Cashew	Mango	Sweet orange
Animal fat (ANF)	0.00	5.72 (0.04)	ND	5.15 (0.10)	4.56 (0.02)
Bleached palm oil (BPO)	0.00	8.00 (0.02)	3.43 (0.12)	5.92 (0.08)	5.14 (0.12)
Sheabutter (SHB)	0.00	7.31 (0.02)	xND	5.00 (0.05)	4.90 (0.10)
Vegetable oil (pure soya oil) (VGO)	0.00	7.35 (0.05)	ND	4.26 (0.11)	4.56 (0.03)
Uncoated fruit	0.00	7.35 (0.01)	ND	5.71 (0.05)	5.46 (0.01)
Fresh fruit (Before storage)	0.00	8.14 (0.02)	5.72 (0.01)	5.72 (0.01)	5.71 (0.05)

Values represent average of 3 determinations (± Standard Error of Mean)
ND: Not determined due to deterioration

Table 3. Total soluble solid contents (%) of fat/oil coated fruits under storage (at 28±2ºC) for 7 days

Coating agent	Ripened fruit samples				
	Avocado	Banana	Cashew	Mango	Sweet orange
Animal fat (ANF)	0.00	14.0 (0.06)	6.0 (0.12)	9.5 (0.10)	9.2 (0.08)
Bleached palm oil (BPO)	0.00	13.0 (0.13)	ND	8.7 (0.07)	8.5 (0.11)
Sheabutter (SHB)	0.00	13.0 (0.10)	ND	7.5 (0.03)	8.0 (0.05)
Vegetable oil (pure soya oil) (VGO)	0.00	10.0 (0.01)	ND	9.0 (0.05)	8.0 (0.02)
Uncoated fruit	0.00	13.1 (0.06)	ND	10.0 (0.05)	9.5 (0.06)
Fresh fruit (Before storage)	0.00	16.0 (0.07)	10.0 (0.01)	10.0 (0.03)	10.2 (0.05)

Values represent average of 3 determinations (± Standard Error of Mean)
ND: Not determined due to deterioration

Table 4. Total titratable acidity (as citric acid) of fat/oil coated ripened fruits in storage (at 28±2ºC) for 7 days

Coating agent	Ripened fruit samples				
	Avocado	Banana	Cashew	Mango	Sweet orange
Animal fat (ANF)	0.014 (0.003)	0.018	ND	0.030	0.019
Bleached palm oil (BPO)	0.017 (0.001)	0.024	0.038	0.019	0.039
Sheabutter (SHB)	0.012 (0.004)	0.016	ND	0.022	0.162
Vegetable oil (pure soya oil) (VGO)	0.010 (0.001)	0.021	ND	0.018	0.018
Uncoated fruit	0.010 (0.002)	0.013	ND	0.045	0.072
Fresh fruit (Before storage)	0.011 (0.01)	0.045	0.088	0.052	0.183

Values represent average of 3 determinations (± Standard Error of Mean)
ND: Not determined due to deterioration

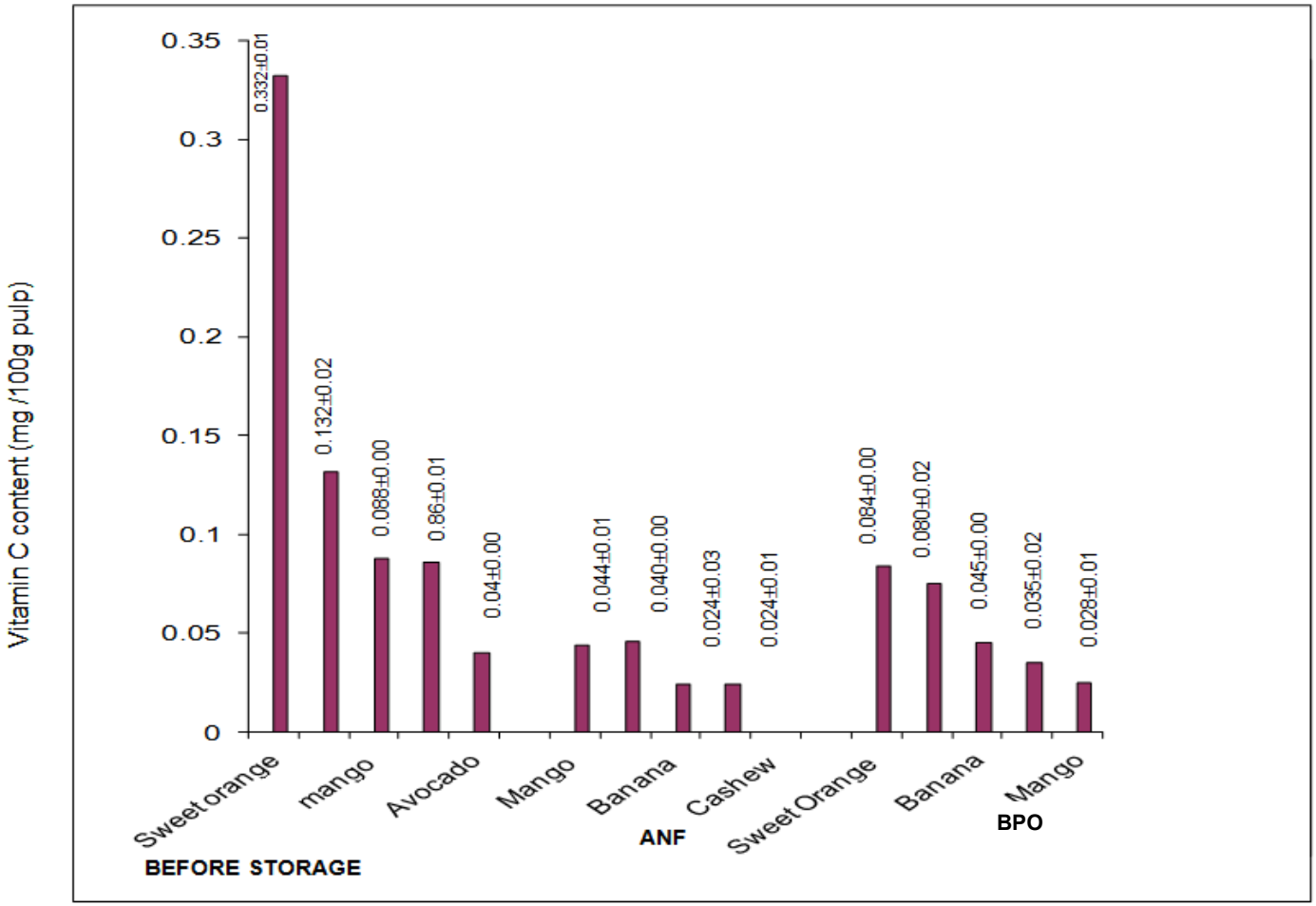

Fig. 1a. Vitamin C content of Fat/oil coated fruits under storage. (at 28±ºC) for 7 days, ± standard error of the means

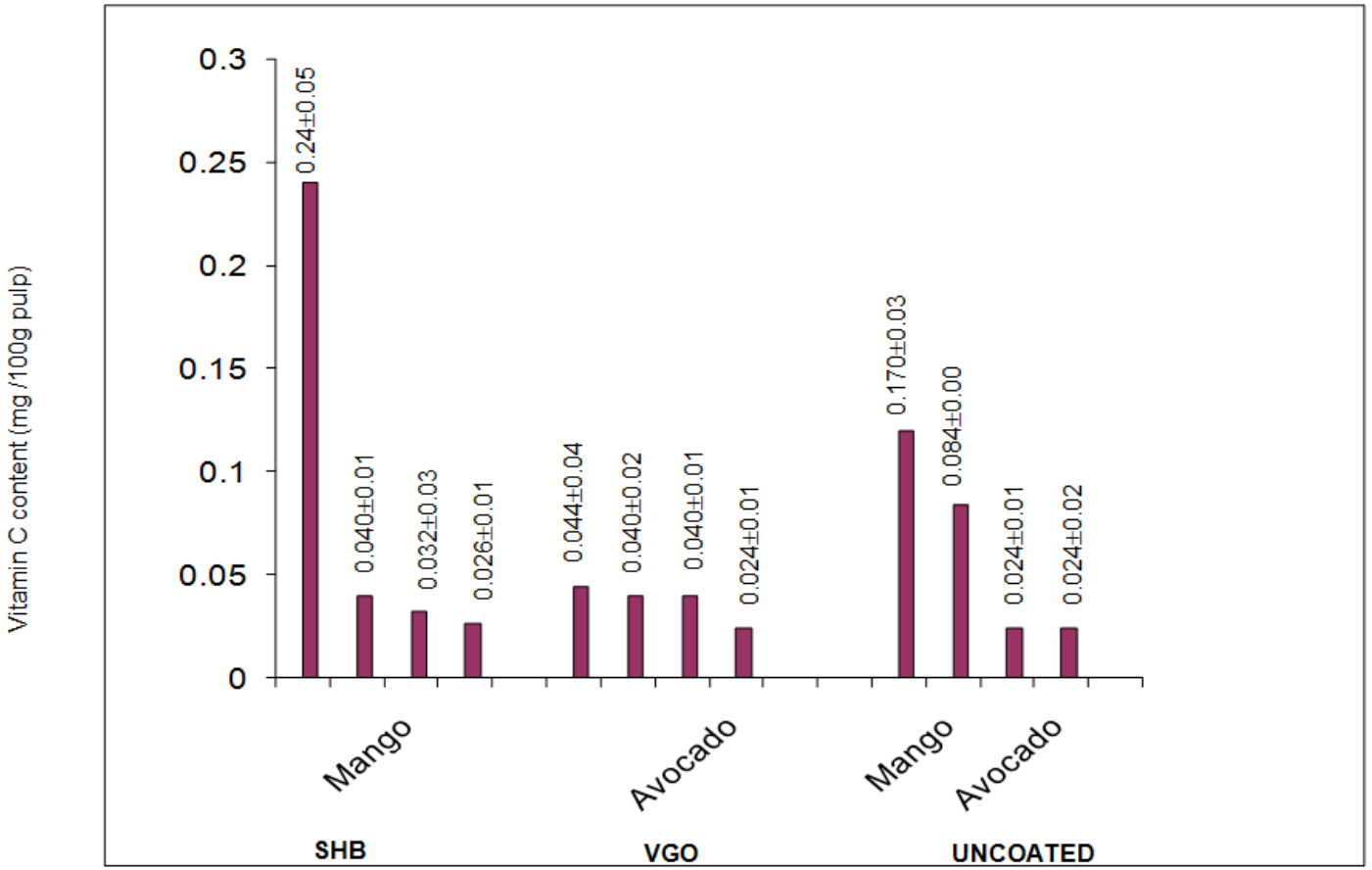

Fig. 1b. Vitamin C content of fat/oil coated fruits under storage. (at 28±ºC) for 7 days, ± standard error of the means

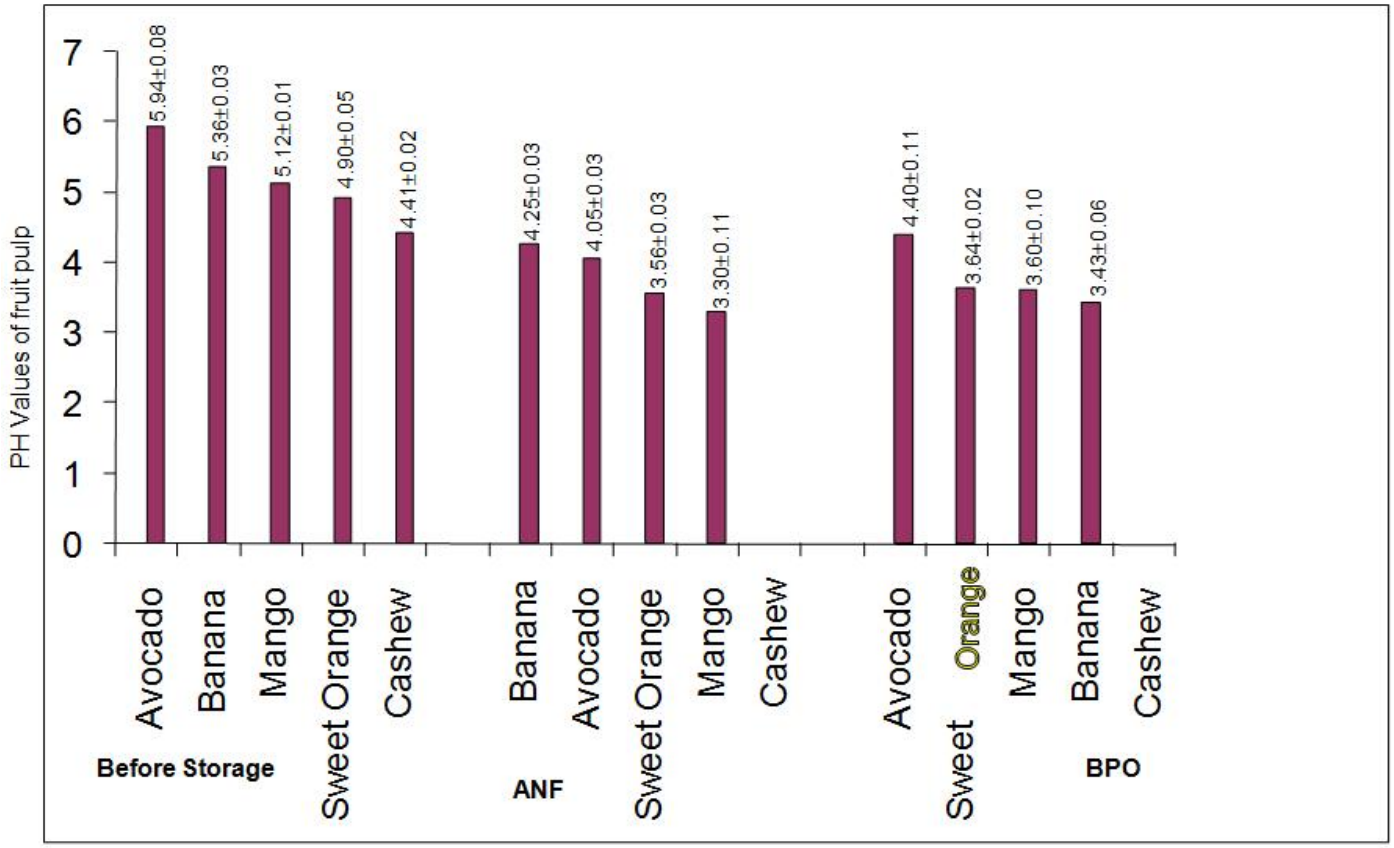

Fig. 2a. pH values of fat/oil coated fruits in storage. (28±2ºC) for 7 days, ± standard error of the means

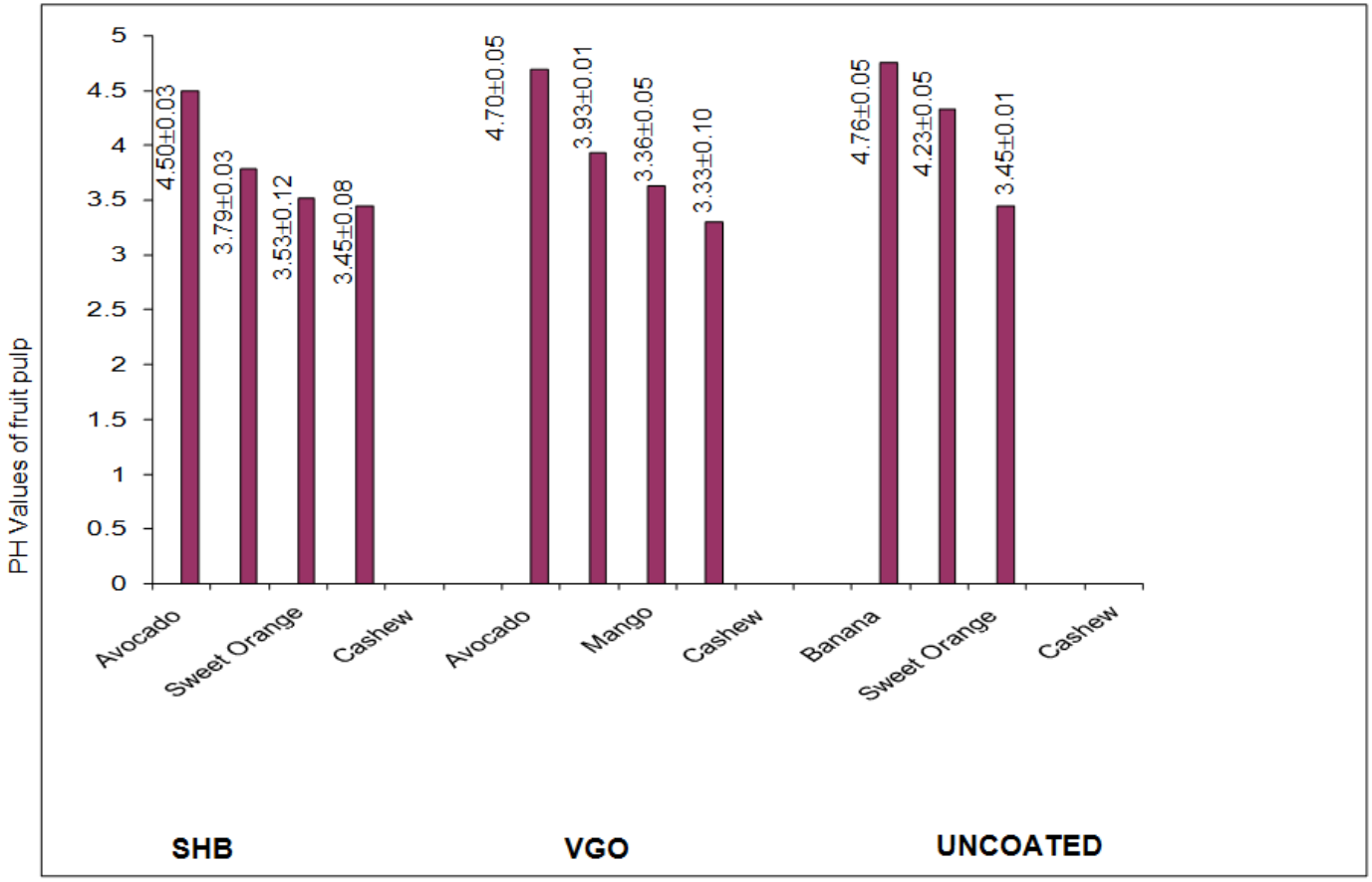

Fig. 2b. pH values of fat/oil coated fruits in storage. (28±2ºC) for 7 days, ± standard error of the means

4. CONCLUSION

The study investigated the biochemical parameters and vitamin C contents of some tropical fruits as affected by coating with four different edible fats/oils. Sheabutter (SHB) and vegetable oil (VGO) were found most suitable fat/oil as coating agents for the retention of moisture, vitamin C, soluble solid contents and preservation of freshness of ripe banana; sweet orange, avocado and mango for the purpose of extending storage life of the fruits to allow for distribution/marketing before reaching the consumers' tables.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=747&id=22&aid=7189