Stabilized Avocado Pastes: Chemical Contents and Oxidative Changes During Storage

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Abstract: The nutritive compositions and oxidative stabilities of processed avocado pastes at ambient (30±1°C, RH80%) and refrigerator (5-6°C) storage temperatures were evaluated and studied. Avocado pulp was blended with ingredients, chilled, kneaded and shaped. For oxidative studies varying concentrations and combinations of Ascorbyl palmitate (AP) and Propyl gallate (PG) were blended with the pulp. Products were evaluated for their proximate composition, minerals and vitamin C contents. Stored products at ambient and refrigerated temperatures for 16 days, were evaluated for contents of free fatty acids (FFA), peroxide values (PV), thiobarbituric acid values (TBA), also changes in colour, odour and flavour/aroma. The protein, carbohydrates and lipid contents of control (untreated) and stabilized pastes ranged from 2.7-2.8%, 9.2 - 9.5% and 32.8-33.4%, respectively. The results of mineral analysis and their implications on human nutrition are discussed. Vitamin C contents ranged from 20.6-22.8mg/100g. Generally, stored products had lower FFA contents, PV and TBA values from days 0-4 and 0-8 at ambient and refrigerator temperatures, respectively. Highest percent FFA, PV and TBA values were obtained in the control samples while least values were recorded in products stabilized with AP+PG, 200/200ppm. The efficacy of the preservatives were of the order of AP+PG, 200/200ppm > AP+PG, 100/100ppm>AP, 200ppm>PG200ppm>untreated control. AP+PG, 200/200ppm significantly ($P \leq 0.05$) reduced % FFA, PV and TBA values in stored products and synergistically stabilized their colour, odour and flavour/aroma for 4 and 8 days at ambient and refrigerator storage temperatures, respectively.

Keywords: Avocado pastes, ascorbyl palmitate, propyl gallate, stabilized, stored products, treated, oxidative, composition, minerals, vitamin C, ambient, refrigerated.

INTRODUCTION

The avocado pear *Persea americana*, Mill is a highly nutritious fruit that is widely cultivated in the tropical and subtropical regions, up to 43° latitude [1]. It contains about 5-36% lipids and has become an accepted part of the diet of many people in developed countries where it is eaten as fresh fruit [2]. Its fat contents make it a valuable source of energy as well as a potential raw material for the manufacture of pleasantly tasting spreads for breads and biscuits. Besides, the lipids contain linoleic acid [3,4] a polyunsaturated fatty acid which together with alpha linoleic acid (Omega-3 fatty acid) form vital parts of body structures, perform important roles in immune system and vision, help form cell membranes and produce hormone-like compounds called eicocasnoids [5].

Fats and oils play important roles in human nutrition and their sources, composition and extraction process determine their end use. Oils from major oilseeds like groundnuts, palm fruits, sunflower seed, safflower seed and soybean have been utilized in the manufacture of margarine with success [6]. However fats and oils from lesser-known vegetable sources such as the avocado pear, African oil bean and melon seed are yet to be investigated and their potentials for wider application in various food formulations exploited. Ripe avocado pear deteriorates rapidly [7] due to softening and discolouration of fruit pulp that is attributable to microbial attack and oxidative changes [8]. Heat processing of avocado pear has presented considerable problems to interested food processors because the fat contents tend to predispose the paste to oxidative rancidity and also confer resistance to microorganisms that are entrapped in fat globules. Additionally, since lipid oxidation is a chemical reaction with a low activation energy, the rate of this reaction is not significantly diminished by lowering the temperature of storage [9]. Lipid oxidation of vegetable oils may be minimized by the use of antioxidants [10]. Mepba [11] reported flavour/aroma changes in high temperature processed coconut milk held at room and refrigerator temperatures. Similarly, Mepba and Achinewhu [12] achieved prolonged storage of coconut milk using combinations of ascorbyl palmitate and propyl gallate.

Methods for processing peanut kernels for production of a low moisture, light coloured, bland flavoured peanut paste have been reported [13]. Similarly, Upchurch [14] developed a cheese-like spread composed of 50% peanuts and Ganguis *et al*. [15] used curds made from peanut milk in processing cheese-like spread. Avocado is a nutrient-dense food that is abundant in the rainforest regions and savannah grasslands of Nigeria. Processing the pear would reduce its post harvest losses, create further utility and introduce nutritious foods in regions where they are grown. The present study evaluates

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1874-2564/082008 Bentham Open

the nutritional and oxidative stability of processed avocado pastes.

MATERIALS AND METHODS

Sample Preparation

Avocado pear was picked at the mature green stage of development from sixteen stands at different locations on the research farm, Rivers State Institute of Agricultural Research and Training, Onne. The fruits were allowed to ripen off the plant at room temperature within 3-4 days, to allow for optimum processing quality [2].

Samples (2kg) were washed, cut into halves longitudinally and seeds discarded. The pulp was scooped into an aluminium bowl and steam heated for 10mins. To samples (80g) of the blanched pulp was added pasteurized tinned milk, 7½%, egg yolk, 5%, ice crystals, 5% and NaCl, 1.2%. The nonfat ingredients were first blended followed by the addition of the fat phase in a Moulinex Food Processor, Model dePC 3, France. The aqueous and lipid phases were jointly blended at high speed for 20mins followed by chilling of emulsion in an ice bath for 24hrs before kneading and shaping. For oxidative studies, samples were treated with propyl gallate (PG), ascorbyl palmitate (AP) and their combinations as follows: T1, avocado paste blended with distilled water (the untreated control with no antioxidant). T2, avocado paste stabilized with PG (200ppm); T3, avocado paste stabilized with AP (200ppm); T4, avocado paste stabilized with AP (100ppm) and PG (100ppm) and T5, (AP +PG1), avocado paste stabilized with AP (200ppm) and PG (200ppm) (AP+PG2). Samples were further homogenized, pasteurized in a waterbath at 72^{o}C for 5 mins then packed in 42 x 62 cm plastic pouches, heat sealed and refrigerated.

Chemical Analysis

Proximate composition of avocado pastes for moisture, protein (Nx6.25), carbohydrate, lipid and ash were determined by AOAC [16] methods. A known mass (5.0g) of dried ground sample was dissolved in 6M HCL solution and the resulting solution was made to a definite volume (20ml) and used for the determination of mineral elements. Phosphorus was determined by the phosphomolybdate method [17]. Sodium, potassium, calcium, magnesium and iron were determined using the Atomic Absorption Spectrophotometer (Unicam Analytical Instrument, Model 919, Cambridge, UK). Vitamin C was determined by taking 5g sample of each paste and blending it in a mortar with 100ml of 10% (v/v) trichloroacetic acid; the ascorbic acid was assayed by visual titration with 2,6 dichlorophenol indophenol solution.

Storage Studies

Triplicate samples of each experimental paste were stored in a laboratory cupboard at ambient temperature (30±1^{o}C, RH80%). Similarly, triplicate samples of treated and untreated pastes were stored at 5-6^{o}C in Ariston refrigerator (Model ME 140, Italy). Stored products were periodically evaluated for oxidative stability at intervals of 4 days. Stored products were chemically analysed for peroxide and thiobarbituric acid values, respectively, following the methods of Fioriti *et al.* [18] as modified by Erdelyl [19]. Free fatty acid contents of samples were determined by the titrimetric method [20] and FFA contents. expressed as percent oleic acid.

Sensory Evaluation

Triplicate samples of treated and untreated avocado pastes were prepared for room and refrigerated storage temperatures. On day zero, samples were tested against a hidden control (T6) previously prepared and refrigerated. During subsequent tests, refrigerated samples were withdrawn from storage and allowed to equilibrate at room temperature for 20 mins before presentation to panelists. Prepared pastes were sliced with separate knives and presented on white saucers to thirty panelists. The panelists were introduced to intensity scaling and controlled procedures for smelling and tasting the experimental pastes. A range of prepared standard samples with colour, odour and flavour characteristics of oxidized milk such as fishy, grassy and painty were evaluated (Fig. **1**). Avocado pastes exposed to dried fish, fresh cut grass and paint fumes [21] served as standards for fishy, grassy and painty descriptors, respectively, while freshly prepared pastes were used to monitor colour changes. Sensory scores were recorded by utilizing a 7-point descriptive odour and flavour/aroma score sheet (Fig. **1**). Water was provided for rinsing of mouth between tests. Panelists were trained prior to and periodically during the study. During each experimental session panelist evaluated six (T1-T6) randomly presented stabilized avocado pastes in comparison to a marked bland reference T6 for colour, odour and flavour intensities [22].

Scores	Description for colour, odour and flavour/aroma
7.0	Greenish-yellow, odourless, fresh avocado paste flavour/aroma
6.0	Pale-green, odourless, smooth avocado paste.
5.0	Pale-green, odourless, mild avocado paste flavour/aroma
4.0	localized brown specks on the surface, stale, fishy odour, rotten orange flavour/aroma.
3.0	Straw coloured exudates, painty, mild ammonia, formaldehyde, fishy flavour.
2.0	Dark brown paste, grassy odour and fruity flavour/aroma.
1.0	Dark coloured with mushy consistency, putrid, foul smelling odour.

Fig. (1). Descriptive score sheet for colour, odour and flavour intensities of stored avocado pastes.

Statistical Analysis

Experimental Design: A randomized complete block design was used for evaluation of results of proximate contents and elemental analysis. A split-plot arrangement [23] fitted with a complete randomization design involving treatments and storage was used for analysis of oxidative and sensory data. Means of treatment effects on changes in free fatty acids (FFA), peroxide value (PV), thiobarbituric acid value

Table 1. Proximate Composition of Processed Avocado Pastes

Composition	Untreated	PG	AP	AP+PG	AP+PG
	Control T1	(200) T2	(200) T3	*(100/100) T4	(200/200) T5
Moisture (%)	$52.90^{a}\pm0.3$	$^{\Delta}53.5^{c}\pm0.2$	$53.6^{d}\pm0.3$	$53.4^{b}\pm0.2$	$53.6^{d}\pm0.3$
Protein (%)	$2.70^{a}\pm0.1$	$2.80^{a}\pm0.1$	$2.80^{a}\pm0.2$	$2.8^{a}\pm0.2$	$2.8^{a}\pm0.1$
Lipid (%)	$33.2^{c}\pm0.2$	$33.0^{b}\pm0.2$	$32.8^{a}\pm0.3$	$33.2^{c}\pm0.2$	$32.8^{a}\pm0.1$
Carbohydrate (%)	$9.5^{d}\pm0.2$	$9.4^{c}\pm0.1$	$9.3^{b}\pm0.2$	$9.2^{a}\pm0.1$	$9.3^{b}\pm0.2$
Total Ash (%)	$1.7^{c}\pm0.1$	$1.3^{a}\pm0.1$	$1.4^{b}\pm0.1$	$1.4^{b}\pm0.1$	$1.4^{b}\pm0.1$

LSD = 0.1.
*Antioxidant additions (in ppm). T= Treatment, PG = Propyl gallate, AP = Ascorbyl palmitate, AP+PG = Ascorbyl palmitate + Propyl gallate. $^{\Delta}$Values are means ± S.D. of three samples.
LSD = Least significant difference.
^{abcd}Means on the same row followed by different superscripts are significantly different (P≤0.05).

(TBA) and sensory data for stored products held for 16 days at ambient temperature (30±1°C, RH80%) and refrigerator temperatures (5-6°C) were plotted. Data for all measurements were subjected to analysis of variance [24]. Fischer's least significant difference test (LSD) was used to identify significant difference among treatment means.

RESULTS AND DISCUSSIONS

The various treatments to which the avocado pastes were subjected were important to the oxidative stability and sensory acceptability of the pastes. Steam blanching of pastes for instance was considered important to the oxidative and nutritional stability of processed pastes. Although the effect of steam blanching was not monitored in this study, Akobundu [25] reported significant reductions in free fatty acid contents of steam blanched egusi oil (melon seed oil) than fresh seed oil. High free fatty acids in fats and oils accelerate fat oxidation resulting in lowered nutritional value due to destruction of vitamins A and E [26]. Similarly, separate blending of the water soluble and fat soluble ingredients prior to their emulsification by vigorous agitation was to ensure distribution of the water phase as small droplets throughout the continuous oil phase of the processed paste.

Data in Table **1** give the proximate composition of processed avocado pastes. Both the untreated and preserved pastes had protein, carbohydrate, lipid and ash contents ranging from 2.70-2.80%, 9.2-9.5%, 32.8-33.4% and 1.3-1.7%, respectively. No significant differences (P>0.05) were observed in the proximate contents of T3 and T5. The lipid and carbohydrate contents decreased significantly (P≤0.05) between treatments presumably due to leaching of water soluble constituents. Similar observations had been reported for margarine-like products from melon seed [25] and mayonnaise from avocado [27].

Lipid was the major nutrient component of the stabilized pastes. This high fat content of avocado pear makes it a valuable source of energy. Plant oils contain mostly unsaturated fatty acids, ranging from 73-74% of total fat [5]. Avocado oil, similar to canola oil, peanut oil and olive oil contain moderate to high (49-77%) amounts of total fat as monounsaturated fatty acids [5]. Increasing monounsaturated and polyunsaturated fatty acids intake is now recommended as a substitute for saturated fatty acids in the diet to lower

Table 2. Mineral and Vitamin C Contents of Processed Avocado Pastes

	Untreated	PG	AP	AP+PG	AP+PG
Contents (mg/100g)	Control T1	(200) T2	(200) T3	*(100/100) T4	(200/200) T5
K	$385.0^{d}\pm0.4$	$384.7^{c}\pm0.3$	$384.4^{b}\pm0.3$	$384.5^{b}\pm0.2$	$384.1^{a}\pm0.3$
Na	$2.04^{a}\pm0.1$	$1.96^{a}\pm0.1$	$1.95^{a}\pm0.1$	$1.95^{a}\pm0.1$	$1.92^{a}\pm0.1$
Ca	$18.5^{d}\pm0.2$	$18.3^{c}\pm0.2$	$^{\Delta}18.1^{b}\pm0.1$	$18.0^{b}\pm0.1$	$17.8^{a}\pm0.2$
Mg	$25.6^{bc}\pm0.3$	$25.3^{b}\pm0.2$	$25.4^{b}\pm0.3$	$25.3^{b}\pm0.2$	$25.1^{a}\pm0.2$
Fe	$1.8^{b}\pm0.1$	$1.6.^{a}\pm0.1$	$1.5^{a}\pm0.1$	$1.7^{ab}\pm0.1$	$1.5^{a}\pm0.1$
P	$49.2^{d}\pm0.3$	$48.7^{b}\pm0.2$	$48.5^{ab}\pm0.3$	$48.6^{b}\pm0.2$	$48.4^{a}\pm0.2$
Vit. C	$20.6^{b}\pm0.2$	$20.2^{a}\pm0.3$	$22.4^{d}\pm0.3$	$21.8^{c}\pm0.3$	$22.8^{e}\pm0.2$

LSD = 0.2.
*Antioxidant additions (in ppm). T=Treatment, PG = Propyl gallate, AP = Ascorbyl palmitate, AP+PG = Ascorbyl palmitate + propyl gallate. $^{\Delta}$Values are means ± S.D of three sample determinations.
LSD = Least significant difference.
^{abcde}Means on the same row not shearing the same superscripts differ significantly (P≤0.05).

LDL-cholesterol [5]. In fact, monounsaturated fatty acids may be more beneficial, since the low density lipoproteins containing these fatty acids are less likely to be oxidized. Thus consumption of avocado pear and its products with their high contents of monounsaturated fatty acids is beneficial to health.

Data in Table **2** give the mineral contents of the processed avocado pastes. The K, Na and Ca contents of untreated (control) and preserved pastes ranged from 384.1 - 385.0, 1.92-2.04 and 17.8-18.5 mg/100g, respectively. Similarly, Mg, Fe and P contents of the untreated (control) and preserved pastes ranged from 25.1-25.6, 1.5-1.8 and 48.6-49.2mg/100g, respectively. Vitamin C contents of pastes increased significantly ($P \leq 0.05$) with increasing concentrations of ascorbyl palmitate either used singly or in combinations with propyl gallate for preservation.

Similar observations had been reported for coconut milk preserved with propyl gallate, ascorbyl palmitate and their combinations [11].

Data on mineral analysis indicate that the processing treatments caused significant reductions in the K, Ca, Mg, Fe and P contents of the processed pastes. Oladunmoye *et al.* [28]; Mepba *et al*. [29] similarly reported reductions in the K, Na, Ca, Zn, P and Vitamin C contents of blanched leafy vegetables. The results for mineral analysis of processed avocado pastes suggest consumption of large amounts of avocado paste to meet the Recommended Daily Allowance (RDA) for minerals. For instance, adult minimum K requirement for health set by 1989 RDA is 2000mg daily. An adult would require a daily consumption of 520.83g of avocado paste to meet RDA. Potassium is a primary electrolyte and major cation inside the cell and low blood K is a life threatening problem [5]. Consumption of large quantities of avocado paste would be important to meeting the RDA for Na. A Na intake of less than 2g daily increases calcium loss in urine and high intakes can contribute to hypertension in some people [5]. Thus the low Na contents of avocado pear make them suitable for use in Na restricted diets. Calcium is mainly associated with the pectic substances of the cell wall and could significantly influence texture. Its high content in avocado paste is important because the body cells need calcium. Besides, more than 99% of calcium in the body is used as a structural component of bones and teeth. Mg occur in moderate amounts in the processed pastes but this is far below the recommended daily allowance of 400mg daily for men 19-30 years old and 310 mg daily for women 19-30 years old [30]. Similarly, moderate amounts of phosphorus were obtained in the pastes. Phosphorus in a constituent of the cytoplasm and nuclear protein, phospholipids and nucleic acids, as well as taking important part in carbohydrate metabolism. Efficient absorption plus the wide availability in foods make phosphorus a much less important mineral than calcium [30] in the diet. Vegetables are generally poor sources of iron. The iron contents of the processed pastes can be considered low when viewed against an RDA of 8mg, Fe daily for men (19 years and older) and women over 50 years, 18mg daily for girls and women 11 to 50 years old [31]. However, neither the total iron content nor nutrient density of the individual food constitute an accurate guide for choosing dietary sources of iron. Rather the bioavailability of iron present in a meal, which depends on its form and presence or absence of factors that influence absorption and the body's need for iron ultimately determine how much iron that is actually delivered to the body.

Changes in free fatty acids, peroxide and thiobarbituric acid values of processed avocado pastes at ambient temperature (30±1°C) storage are presented in Figs. (**2**-**4**). Propyl gallate and ascorbyl palmitate used either singly or in combinations significantly ($P \leq 0.05$) reduced the percent free fatty acid contents of avocado pastes stored at ambient temperature (30±1°C,RH.80%,) No significant difference ($P > 0.05$) was observed in free fatty acid (FFA) contents of the untreated (control) and samples stabilized with either propyl gallate (PG) or ascorbyl palmitate (AP) on day 0. The FFA contents of the control and stabilized pastes on day 4 ranged from 3.7-6.3%. Significantly ($P \leq 0.05$) higher FFA contents were recorded in all stored products from day 8. Samples stabilized with combinations of AP and PG had significantly lower FFA contents than samples preserved with either AP or PG alone.

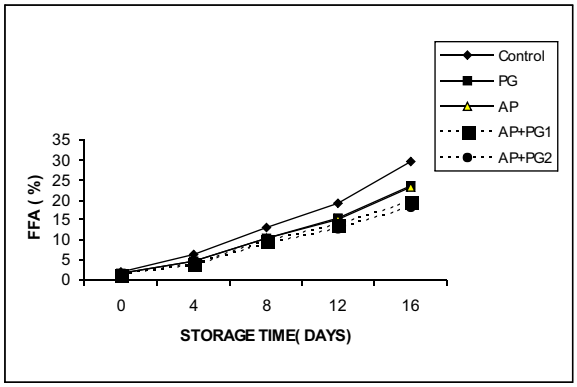

Fig. (2). Changes in FFA with storage time at ambient temperature.

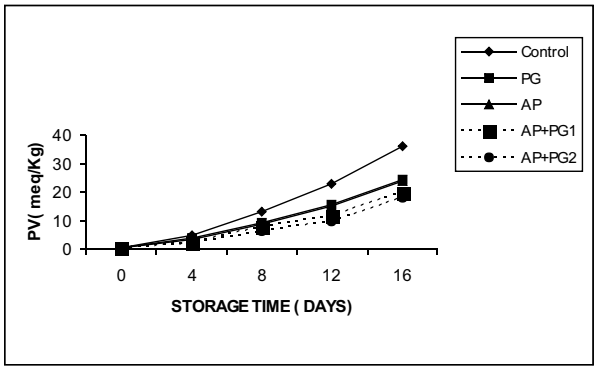

Fig. (3). Changes in PV with storage time at ambient temperature.

The peroxide value PV) and thiobarbituric acid values of products stored at ambient temperature followed the same pattern as the FFA contents (Figs. **3**,**4**). Propyl gallate, ascorbyl palmitate and their combinations significantly ($P \leq 0.05$) reduced peroxidation in stored avocado pastes. No significant differences were observed in the peroxide and thiobarbituric acid values of stored products on day 0. Significantly ($P \leq 0.05$) lower peroxide values were recorded in stored samples up to day 4. Peroxide development and oxidation of stored products increased rapidly from days 8 and 12, respectively to the point of obvious flavour/odour devel-

opment in stored products. Lowest peroxide values were obtained in products stabilized with AP+PG2 and AP+PG1, while highest values were recorded in the untreated control and products stabilized with propyl gallate (PG).

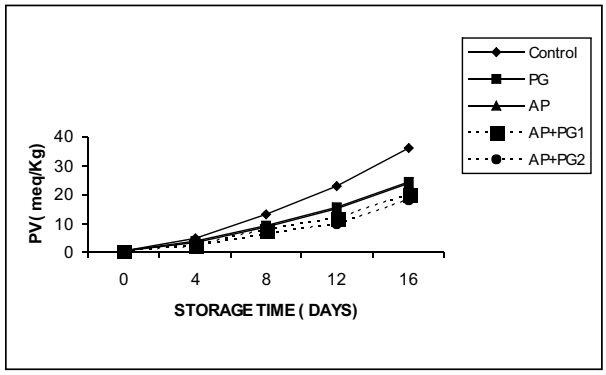

Fig. (4). Changes in TBA with storage time at ambient temperature.

The TBA (532nm) data (Fig. **4**) showed that all antioxidant treatments retarded oxidation in stored products from days 0-16. No significant differences (P>0.05) were observed in the TBA values of the untreated (control) samples and the stabilized pastes on day 0. Lowest TBA values were recorded in samples stabilized with combinations of AP+PG (200/200ppm) from day 4-12, while highest TBA values were recorded in the controls. TBA values for all samples increased significantly (P≤0.05) with prolonged storage. Generally, products had lower FFA contents, peroxide and thiobarbituric acid values from 0-4 days of storage at ambient temperature (30±1˚C,RH80%). Similarly, AP+PG, (200/200ppm) significantly (P≤0.05) retarded lipid oxidation in the avocado pastes as demonstrated by lowest contents of FFA, PV and TBA of products stored at ambient temperature. Increases in TBA values with extended storage periods had been similarly reported [32] and is thought to be related to the amounts of dissolved oxygen in the prepared pastes.

Data in Figs. (**5-7**) give changes in FFA, PV and TBA values of avocado pastes at refrigerator temperature (5-6^{o}C) storage. In all cases significantly (P≤0.05) lower FFA, PV and TBA values were recorded in stored products up to day 8. Lowest FFA, PV and TBA values were obtained in products stabilized with AP+PG2, while highest values were obtained in control samples. The efficacy of the preservative chemicals was of the order of AP+PG2>AP+PG1>AP> PG>control. Thus, although propyl gallate and ascorbyl palmitate significantly (P≤0.05) retarded peroxidation in stored products, a combination of both antioxidants had higher efficacy than any of the antioxidants used singly.

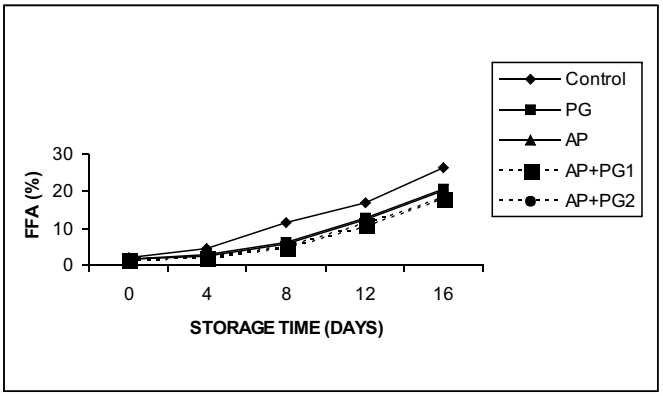

Fig. (5). Changes in FFA with storage at 5-6 ^{o}C

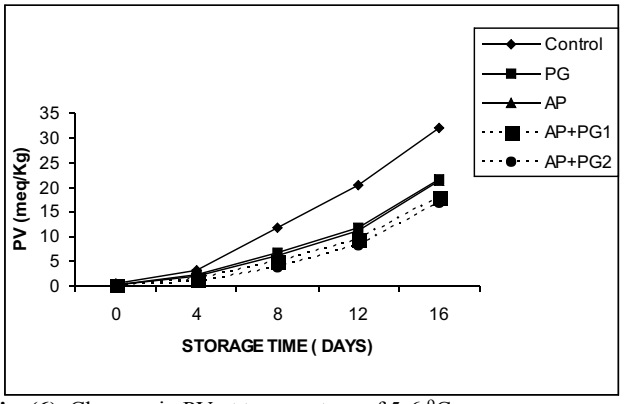

Fig. (6). Changes in PV at temperature of 5-6 ^{o}C.

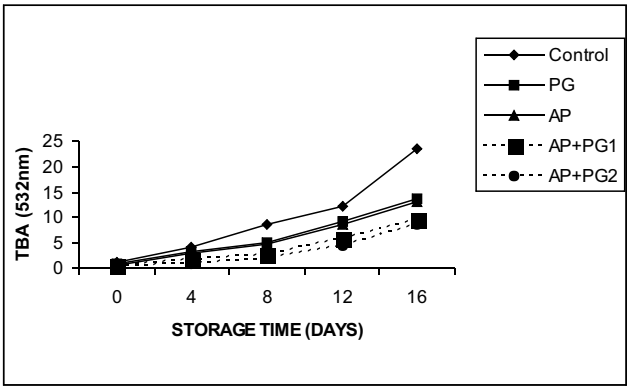

Fig. (7). Changes in TBA with storage time at temperature of 5-6 ^{o}C.

Data in Figs. (**2-7**) show significant increase in peroxidation of stored products with extended storage periods. This was expected. The avocado pear like other oilseeds contain lipoxygenase which in the presence of moisture catalyse the oxidation of fatty acids such as linoleic acids a polyunsaturated fatty acid (PUFA) that occur in high concentrations in the avocado pulp [5] thus liberating free fatty acids. Oleic, linoleic and arachidonic acids made significant contributions to increased rancidity in cooked beef [33]. The variations in treatment effects with storage periods suggest differences in the efficacy of the various antioxidants used in preservation. The statistically non-significant (P>0.05) concentrations of FFA, PV and TBA among stabilized and non-stabilized stored products on day 0, suggest that only sound, mature and ripe fruits were used. The variations in treatment effects with storage periods suggest differences in the efficacy of the antioxidants and their combinations. Mepba and Achinewhu [12] reported that FFA contents and peroxide developments in stabilized coconut milks and the untreated (control) products increased significantly from day 4 to 12 at ambient temperature (30±1^{o}C, RH 80%) storage. Similarly, Iwe [34] reported rapid decline in pH but increased peroxidation of soymilk samples stored at ambient temperature than products at refrigerator temperature, and concluded that stability was enhanced by storage conditions.

The reduced contents of FFA, PV, and TBA of refrigerated products supports the reports of Iwe [34]. This was however influenced by the efficacy of the antioxidants used in this study. For instance, the significantly higher FFA, PV and TBA contents of untreated (control) products from day 4 to 16 suggest that all antioxidants significantly reduced lipid oxidation to varying degrees. Among the phenolic antioxidants, butylated hydroxyl anisole (BHA), butylated hydroxyl toluene (BHT), tert-butyl hydroquinone (TBHQ) and propyl gallate (PG), propyl gallate has consistently shown superior activity in vegetable oils when compared to BHA, BHT and TBHQ [35]. In this study, PG significantly ($P \leq 0.05$) reduced contents of FFA, TBA and peroxidation of stored products at ambient and refrigerator storage temperatures. In combinations, ascorbyl palmitate and propyl gallate significantly reduced peroxidation, FFA and TBA values than either of the antioxidants used singly. Chemical analysis showed that PG delayed paste oxidation but to a lesser extent than AP and AP+PG1. Ascorbyl palmitate (AP) compared favourably with AP+PG1. Thus it appeared that as AP levels increased, the combinations of AP+PG became more effective as an antioxidant. Pongracz [36] reported that addition of increasing amounts of AP to sunflower oils extended protection from oxidation. The improved antioxidant activity of AP over PG suggested that AP has greater antioxidant activity than PG. Similar observations had been reported in canola oils [35].

Data in Figs. (**8**-**10**) give panel mean scores for colour, odour, flavour/aroma intensities in stored avocado pastes at ambient temperature (30±1°C, RH 80%) for 16 days. Stored products stabilized with AP and PG or their combinations did not vary significantly ($P > 0.05$) from the freshly prepared hidden control in their colour, odour, flavour and aroma scores on day O. The hidden control was rated significantly ($P < 0.05$) higher than all the stored products for the tested sensory attributes from the 4th to 16th day of storage. There were no significant differences ($P > 0.05$) in panel scores for colour in products stabilized with AP and AP+PG1 at ambient temperature storage. Similarly, there were no significant colour changes for products stabilized with PG and the untreated (control samples) on days O, 4 and 16 at ambient temperature storage.

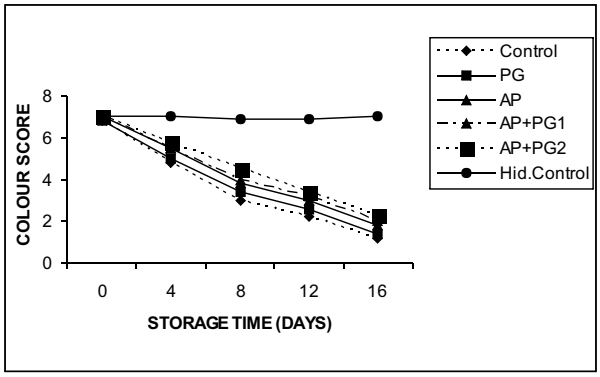

Fig. (8). Colour scores at ambient temperature.

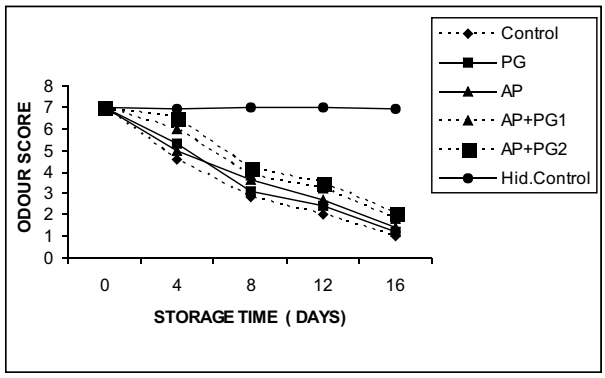

Fig. (9). Odour scores at ambient temperature.

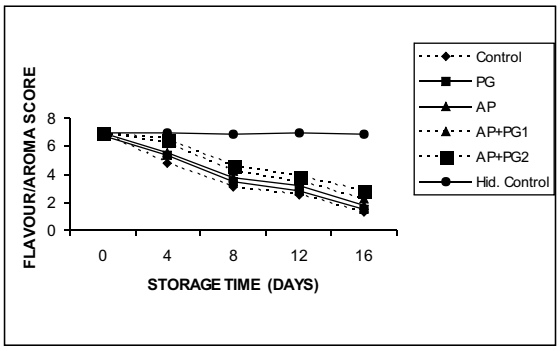

Fig. (10). Flavour/aroma scores at ambient temperature.

Significant shifts ($p \leq 0.05$) in odour intensities (Fig. **4**) of stored products commenced from day 4 and increased in intensities as storage progressed to day 16. Panel ratings for odour differed significantly ($p \leq 0.05$) within treatments and decreased as storage progressed.

Panel scores for flavour/aroma of stored products at ambient temperature followed similar trends as for odour intensities. Products stabilized with PG, AP and the untreated control had mild avocado paste flavour/aroma while products stabilized with AP+PG1, AP+PG2 and the freshly prepared hidden control had smooth avocado paste flavour/aroma on day 4. Further deterioration in flavour/aroma intensities (Fig. **10**) was heightened after day 8.

Data in Figs. (**10**-**13**) give panel scores for colour, odour and flavour/aroma of avocado pastes at refrigerated temperature (5-6°C) storage. As in products stored at ambient temperature, there were no significant differences ($p > 0.05$) in the colour intensities of the untreated control and products stabilized with propyl gallate (PG). Panelists rated products stabilized with AP, AP+PG1 and AP+PG2 significantly higher for this attribute on day O. Products stabilized with AP, AP+PG1 and AP+PG2 had varying shades of pale-yellow colour. There were localized brown specks on the surface of untreated control pastes on day 8 while PG, AP, AP+PG1 and AP+PG2-stabilized products had varying intensities of pale yellow colour. Colour deterioration ensued after day 8 with varying shades of straw-coloured exudates and dark brown pastes in the untreated control, PG and AP-stablized pastes on days 12 and 16. There were localized brown specks and straw-coloured pastes in AP+PG1 and AP+PG2 –stabilized pastes within the same period. Similar observations were made for odour and flavour/aroma intensities of products at refrigerated temperature storage. Significant improvements in organoleptic attributes of stored products at refrigerator temperature resulted in extended shelf stability of up to 8 days for the stabilized samples. Significantly ($p \leq 0.05$) higher colour, odour and flavour/aroma

scores were made for AP+PG2 – stabilized pastes while fastest rate of deterioration was recorded in the untreated control pastes.

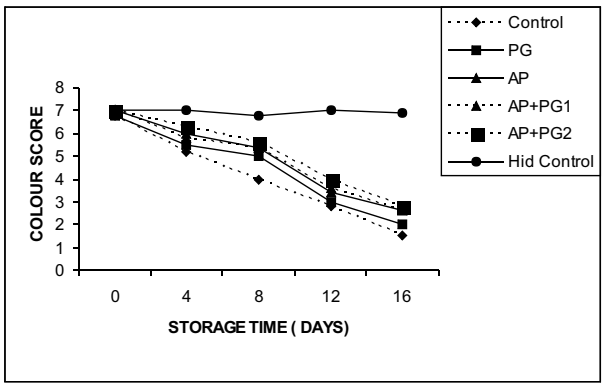

Fig. (11). Colour scores at temperature 5-6 ^{o}C.

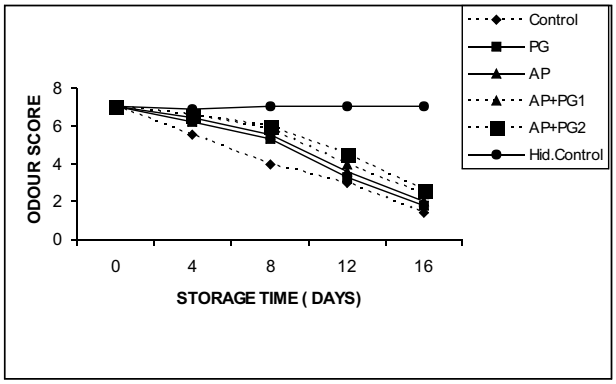

Fig. (12). Odour scores at temperature 5-6 ^{o}C.

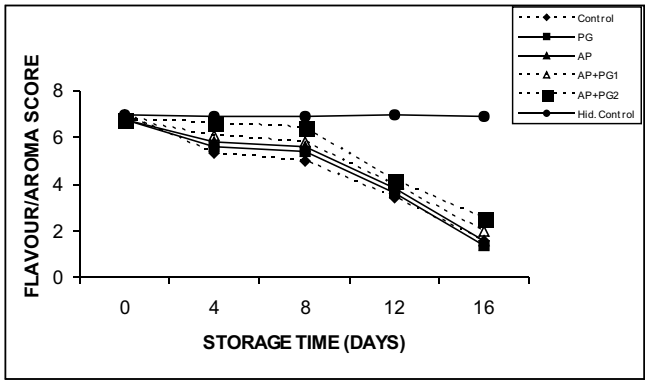

Fig. (13). Flavour/aroma scores at temperature 5-6 ^{o}C.

The results above (Figs. **2-13**) corroborate the reports of Mepba and Achinewhu [11]. Lipid oxidation is a major cause of decrease in the colour, odour also flavour/aroma and nutritive value of fat and oil products. The rate and degree of antoxidative degradation has been directly related to the degree of unsaturation of the lipids present [32]. The avocado pear is high in oleic and linoleic acids [4] which play significant roles in human nutrition. According to Golkalp *et al.* [33], oleic, linoleic and arachidonic acids made significant contributions to increased rancidity of cooked beef. The reaction of oxygen with unsaturated fats results in the formation hydroperoxides which then decompose to form aldehydes, ketones, alcohols and lactones [32]. Such short chain carbon compounds can impact off-flavours and off-odours to stored products [37].

CONCLUSION

Procedures for the production of stabilized avocado pastes and evaluation of their chemical contents and oxidative stabilities under ambient and refrigerated storage temperatures were investigated. The protein, lipid and carbohydrate contents of unstabilized and stabilized pastes ranged from 2.7-2.8%, 32.8-33.2% and 9.2-9.5%, respectively while the K, Na, Ca, Mg, Fe and Vitamin C contents ranged from 384.1-385.0, 1.92-2.04, 17.81-18.5, 25.1-25.6, 1.5-1.8 and 20.6-22.8mg/100g, respectively. Highest percent free fatty acid (FFA), peroxide value (PV) and thiobarbituric acid (TBA) values were obtained in the control samples (TI) while least values were recorded in products stabilized with combinations of ascorbyl palmitate and propyl gallate (AP+PG, 200/200ppm). The efficacy of the preservative chemicals were of the order of AP+PG2 >AP+PG1> AP>PG> untreated control. AP+PG, 200/200ppm significantly ($P \leq 0.05$) reduced % FFA, PV and TBA values in stored products and synergistically stabilized their colour, odour and flavour/aroma for 4 and 8 days at ambient and refrigerator storage temperatures, respectively.

RECOMMENDATION

Studies on the microbiological quality and sensory acceptability of stabilized avocado pastes at ambient and refrigerator temperatures would be important to the shelf live of processed avocado pastes.

REFERENCES

[1] Gaillard JP, Godefrey J. Avocado. In*:* The Tropical Agriculturist*,* Tindall HD, Ed. Macmillan Education Ltd. London 1999; 8-14.

[2] Verhiji FWN, Coronel RF. Edible fruits and nuts. No.2. plant Resources of South-east Asia. Pudo, Wagenningen, The Netherlands 1996; 26-32.

[3] Jackson EA. Resources for information on herbal medicines and dietary supplements. J Herb Pharm 2003; 3: 57-64.

[4] Bergh BO. The avocado and human nutrition II. Avocado and your heart. In: Proceedings of the 2nd World Avocado Congress. Los Angeles 1998; 2: 37-47.

[5] Wardlaw GM, Kessel MW. Perspectives in Nutrition (5th ed). McGraw-Hill Companies Inc. New York, USA, 2002.

[6] Ihekoronye AL. Cereal and Oilseed Processing Technology. In: Manual on small-scale food processing. The Academic publishers, Enugu, Nigeria 1999; 40.

[7] Nwufo MI, Okonkwo MI, Obiefuna JC. Effects of post harvest treatments on the storage life of avocado pear (Persea Americana Mill*).* Trop Sci 1996; 34: 364-370.

[8] Okaka JC. Tropical Plant Perishables. Handling, processing and storage of fruits and vegetables. Silicon valley publishers, Enugu, Nigeria 2005; 28-40.

[9] Hans DY, Shin HK. Antioxidative effect of ascorbic acid solubilized in oils *via* reversed micelles. J Food Sci 1990: 55: 247-249.

[10] McMillan AJ, Wong H, Wills RRH. Fat uptake during deep fat frying of coated and uncoated foods. J Food Comp Anal 2004; 1: 93.

[11] Mepba HD. Effects of processing methods and storage on the qualities of coconut milk. Discov Innov 2002; 15: 45-56.

[12] Mepba HD, Achinewhu SC. Microbiological and oxidative stability of high temperature processed coconut milk at refrigerated storage. Dicov Innov 2003; 15: 45-56.

[13] Santos BL, Resurreccion AVA, Garcia TD. Quality characteristics and consumer acceptance of peanut-based imitation cheese-spread. J Food Sci 1990; 54: 468-71.

[14] Upchurch W. New peanut cheese product. Res Farm 1994; 37: 2-14.

[15] Ganguis AH, Abdel B, El-Neshawy AA, El-shafy NM. Peanut curd in the manufacture of processed cheese-like spread. Dairy Ind Int 1998; 50: 37.
[16] AOAC: Official Methods of Analysis. Association of Official Analytical Chemists (16th ed.), Washington DC; 1995.
[17] Yuen SH, Polland AO. The determination of phosphorus in plants and soils by molybdate method. J Sci Food Agric 1955; 61: 223-25.
[18] Fioriti JA. Measuring flavour deterioration of fat, oils and dried emulsions in foods. J Am Oil Chem Soc 1997; 54: 450.
[19] Erdelyl A. Autoxidation of fatty acids produced from natural fats and inhibition of oxidative rancidity. In: Fat Science. Proceedings of 17th ISF Congress, Budapest 1983; 42-48.
[20] Egan H, Kirk RS, Sawyer R. Chemical Analysis of Foods (8th ed.), London; 1981.
[21] Kelleher SD, Silva LA, Hultin HO, Wilhem KA. Inhibition of lipid oxidation during processing of washed minced Atlantic mackerel. J Food Sci 1992; 57: 1103-08.
[22] Vaisey-Genser M, Ylimak G. Effects of non absorbable antioxidant on conola oil stability during accelerated storage and to a frying temperature. Proc Can Inst Food Sci Tech 1985; 1: 18-67.
[23] Milliken GA, Johnson DE. Analysis of Messy Data Designed Experiments. Life time learning publications. Belmont CA 1984; 1: 16-22.
[24] Wahua TAT. Applied statistics for scientific studies. Africa Link Press, Aba, Nigeria 1999; 120-155.
[25] Akobundu ENT. Preliminary study on the production of margarine – like product from melon seed (Colocynthis citrullus L) oil. J Food Agric 1990; 2: 131-32.
[26] Potter NN, Hotchkiss JA. Food Science. The AVI Publishing Company Inc Westport CT 1999; 130-150.
[27] Isa FO, Adesala SO, Olaosebikan OO. Production of mayonnaise from avocado pear (Persea Americana). Proceedings: 31st Annu Conf of the Nigerian Inst of Food Sci & Technologists. Raw Material Research and Development Council, Abuja, Nigeria 2007; 13: 107-108.
[28] Oladunmoye OO, Ojeniyi S, Bankole AO. Mineral composition of tender and matured cassava leaves after home cooking procedures. Proceedings: 29th Annu Conf of the Nigerian Inst of Food Sci & Tech Enugu State University, Abakaliki, Nigeria 2005; 151-152.
[29] Mepba HD, Eboh L, Banigo EB. Effect of processing treatments on the nutritive composition and consumer acceptance of some Nigerian edible leafy vegetables. African J Food Agric Nutr Dev 2007; 7: 1-18.
[30] FNB. Food and Nutrition Board, Institute of Medicine. Dietary Reference Intakes for calcium, phosphorus, magnesium, vitamin D and fluoride. National Academy Press, Washington DC; 1997.
[31] FNB. Food and Nutrition Board, Institute of Medicine. Dietary Reference intakes for vitamin A, vitamin K, vitamin C, molybdenum, nickel, silicon, vanadium and zinc. Standing committee on scientific Evaluation of Dietary Reference intakes. National Academic Press, Washington DC; 2001.
[32] Brewer MS, Ikins WH, Harbers CAZ. TBA values sensory characteristics and volatiles in ground pork during long-term frozen storage: Effects of packaging. J Food Sci 1994; 57: 558-63.
[33] Golkap HV, Ockerman HW, Plimpton RF, Harper WJ. Fatty acids of neutral and phospholipids: rancidity scores and TBA values as influenced by packaging and storage. J Food Sci 1983; 48: 829.
[34] Iwe MO. Pattern of spoilage of soymilk: Influence of preparation methods and storage conditions. Nigerian Food J 1991; 9: 22-25.
[35] Hawrysh ZJ, Erin MK, Lin YC, Hardin RT. Propyl gallate and ascorbyl palmitate affect stability of canola oils in accelerated storage. J Food Sci 1992; 57: 1234-38.
[36] Pongracz G. Antioxidant Mixture for use in food. Int J Vit Nutr Res 1990; 43: 517.
[37] Gray JI. Measurement of lipid oxidation: A review. J Am Chem Soc 1990; 55: 539.

Received: March 27, 2008 Revised: April 29, 2008 Accepted: June 06, 2008