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Efficacy of bio-based extracts on shelf life and quality of orange (*citrus sinensis*) fruits during storage in Makurdi, Nigeria

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Abstract

Experiment was conducted at the Biological Sciences Laboratory of Benue State University, Makurdi, Nigeria to determine the efficacy of bio-based extracts (Aloe vera and Gum arabic) on shelf-life and quality of sweet orange. Healthy orange fruits of two varieties (Valencia and Washington) used in the trial were picked at harvest maturity. The experimental design was a 2 x 4 factorial combination, fitted in a completely randomized design and replicated three times. The treatments consisted of two varieties of sweet orange and four extracts regimes (Aloe vera, Gum arabic, Aloe vera+Gum arabic and Control). The orange fruits were treated by dipping in extracts the various treatments until they were completely coated while the control fruits were not treated. The treated fruits and control were stored at ambient conditions of light and temperature for four weeks. Percentage weight loss, total soluble solids, fruit firmness, Vitamin C/Ascorbic acid content, pH, titratable acidity, decay percentage (DP %), marketability and shelf life of the fruits were recorded. The data were subjected to Analysis of Variance (ANOVA) using GENSTAT statistical package, and mean separation was done using Fisher's Least Significant Difference (F-LSD) at 5% level of probability. Percent weight loss, fruit firmness, % decay and fruit marketability were significantly higher (P≤0.05) in Valencia compared with Washington. Fruits treated with Gum Arabic had significantly lower % weight loss and % decay compared with the control (P≤0.05). Fruit firmness was significantly higher (P≤0.05) in fruits treated with Gum Arabic + Aloe Vera while marketability was significantly higher in Aloe Vera treated fruits. All the treated fruits had significantly higher (P≤0.05) shelf life compared with the control. With respect to nutritional values, TSS was significantly higher (P≤0.05) in Valencia compared with Washington while Vitamin C and pH were significantly higher (P≤0.05) in Washington compared with Valencia. The TSS was significantly higher (P≤0.05) in Aloe Vera and Aloe Vera + Gum Arabic treated fruits compared with the control. The Vitamin C content of fruits treated with Gum Arabic was significantly (P≤0.05) higher followed by Aloe Vera + Gum Arabic compared with the control. All the treated fruits had significantly higher pH while TA was significantly lower (P≤0.05) compared with the control. Percent weight loss was positively and significantly correlated with % decay while marketability, shelf life, TSS, and TA were negatively and significantly correlated. The botanicals tested are environmentally friendly, cost-effective, easy to produce and also safe for consumers. The bio-based extracts of *Aloe vera* and Gum Arabic are recommended in the storage of flesh sweet orange fruits.

Keywords: Citrus; Sweet Orange; Gum Arabic; Aloe Vera; Bio-based preservatives; Fruit quality; Shelf life; Storage.

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1. Introduction

Sweet orange (*Citrus sinensis* L.) belonging to the family Rutaceae is one of the most widely grown fruit crops in the world (Liamngee *et al*., 2018). It is a major source of vitamins, especially vitamins A, C, D, B1 and B2 as well as good amount of folacin, calcium, iron, potassium, thiamine, niacin and magnesium with high antioxidant potential (Angew, 2007).

The nutritional importance of fruits is due to the presence of these functional food ingredients and antioxidant, nutreceuticals or phytochemicals. Phytochemicals are present in edible fruits and when eaten, potentially modulate human metabolism in a favourable manner, thereby preventing chronic and degenerative diseases (Tripoli *et al*., 2007).

Economically, sweet oranges are important fruit crops, with an estimated world production of 146.6 million metric tonnes with Nigeria contributing 4.1 million metric tonnes of the total world production (FAO, 2018). Though oranges possess enormous benefits, it has low shelf life due to reasons such as loss of fruit firmness, desiccation, rot/decay caused by pathogenic infections or environmental disorders. In the marketing chain of sweet oranges, fungal rot has been identified as potential factor for causing huge economic losses. It was estimated that in developing countries about 30-40% of total oranges production was lost due to post-harvest fungal infection and decay (Janisiewicz and Korsten, 2002; Yushau, 2017).

Various synthetic chemicals like mancozeb, benomyl, carbendazim, and thiabendazol have gained popularity among growers for control of postharvest diseases of fruits for improvement of the storage life (Lee *et al*., 2009). The use of these synthetic preservatives poses serious health hazards and leads to environmental pollution (Okinbo and Osuinde, 2003). Furthermore, due to their frequent application, there is a tendency of development of resistance in pathogen populations (Kumar *et al*; 2007). With the growing health consciousness among people and increasing consumer demand for pesticide residue free agricultural commodities (Cutler and Cutler, 1999; Serrano *et al*., 2005) it has been the goal of many plant scientist to find alternatives that are cost effective, non-toxic and eco-friendly. *Aloe vera* gel-based edible coatings have been shown to prevent loss of moisture and firmness, control respiratory rate and maturation development,delay oxidative browning, and reduce microorganism proliferation on sweetcherries (Lin and Zhao, 2007).Gum Arabic as a emulsifying, stabilizing and binding properties and has been used postharvest edible coatings in some fruits and vegetables to extend shelf-life of fresh produce (Tiamiyu *et al*.,2023) The objective of this research was to assess the effect of *Aloe vera* gel and Gum Arabic,(Bio-based extracts) on shelf life and quality attributes of sweet orange fruits during storage.

2. Materials and methods

The experiment was conducted at the Botany Laboratory, Benue State University, Makurdi, Nigeria between July and December 2019. Healthy sweet oranges of two varieties (Valancia and Washington) were harvested manually using a secateur to cut at the bottom of the fruits at harvest maturity from Yandev orchard, Benue State, Nigeria. The orange fruits were transported immediately to the laboratory for the study

Gum Arabic was obtained from Nigeria Stored Products Research Institute (NSPRI) Ilorin, Kwara State, in aqueous form while *Aloe vera* was harvested from Yandev orchard farm in Gboko metropolis to extract the gel for the experiment. Fully expanded, mature, healthy and fresh leaves of *Aloe vera* were collected using a sharp knife and washed with clean water then with sterile distilled water. The tapering point of the leaf top and the short sharp spines located along the leaf margins were removed by a sharp knife and then the knife was introduced into the mucilage layer below the green rind avoiding the vascular bundles then the *Aloe vera* gel was obtained. After separating the Aloe vera gel from the outer cortex, the colourless hydro parenchyma was then blended to remove fibers and then put in clean and sterilized glass bottles. These bottles were stored in the fridge at 4 - 8ºC until ready for use. The liquid obtained constituted fresh *Aloe vera* gel as reported by Liamngee *et al.* (2017). To obtain the combination of *Aloe vera* gel and Gum Arabic, 25% of *Aloe vera* gel and 25% of Gum Arabic were mixed together to give a 50% combination.

The cleaned fruits were completely immersed in the medium of 50% *Aloe vera* gel, 50% Gum Arabic and 25% *Aloe ver*a gel + 25% Gum Arabic and allowed to stay for four minutes. Thereafter, they were removed, air dried and placed in plastic crates and stored at room temperature.

The experiment was a 2 x 4 factorial combination of treatments fitted in a completely randomised design (CRD) and replicated three (3) times. The treatment consisted of two varieties of sweet orange (Valencia and Washington) and three regimes of plant extracts (f *Aloe ver*a gel, Gum Arabic, *Aloe ver*a gel + Gum Arabic) and a control where no

application of *Aloe vera* gel or Gum Arabic was made. This resulted in 24 treatment units and for each unit ten fruits were used giving a total of 240 orange fruits for the experiment. The treated and control fruits were stored for four weeks after which data were recorded. The date collected include percentage weight loss(%), total soluble solids (TSS), fruit firmness, Vitamin C/Ascorbic acid content, pH, titratable acidity (TA), % decay , marketability and shelf life. The collected data was subjected to Analysis of Variance (ANOVA) using GENSTAT statistical package 17.1DE (2017) and where significant difference was observed, Duncan new multiple range test (DNMRT) at 5% level of significance was used to separate the means.

3. Results

3.1. Effects of *Aloe vera* gel and Gum arabic on physical qualities of sweet orang during storage.

The effect of variety and plant extracts on some physical qualities of sweet orange fruits, four (4) weeks after storage (WAS) is presented in Table 1. . Percent weight loss, fruit firmness, % decay and fruit marketability were significantly higher (P≤0.05) in Valencia compared with Washington. Shelf life of the fruits was significantly higher in Washington compared with Valencia. Fruits treated with Guma arabic had significantly lower % weight loss and % decay compared with the control (P≤0.05). Fruit firmness was significantly higher (P≤0.05) in fruits treated with Gum Arabic + Aloe vera while marketability was significantly higher in Aloe vera treated fruits. All the treated fruits had significantly higher (P≤0.05) shelf life compared with the control. Table 2 presents the interaction effect of variety and plant extracts on the physical and nutritional qualities of sweet orange. Percent weight loss was significantly lowest (P≤0.05) in Valencia treated with Gum Arabic followed by Washington treated with Aloe vera compared with the control. Fruit firmness was significantly higher in Valencia and Washington when treated with Gum Arabic compared with the control. Percent fruit decay was significantly lower (P≤0.05) in both Valencia and Washington fruits treated with Gum arabic. Marketability of the fruits was higher when Valencia was treated with Aloe vera and Aloe vera + Gum Arabic while that of Washington was higher when treated with Aloe vera. All the extract treatments significantly increased the shelf life of both Valencia and Washington.

Table 1 Effect of Variety and Plant extracts on some Physical qualities of sweet orange fruits after four (4) weeks of storage in Makurdi, Nigeria

	N/cm			**Marketability**	
	% Weight loss	**Fruit firmness**	**% Decay**	**Marketability**	**Shelflife (days)**
Variety					
Valencia	26.68	2.60	6.20	3.62	21.00
Washington	27.15	2.61	16.88	2.88	28.00
Plant Extracts					
Aloe vera	20.90	2.60	8.33	5.00	28.00
Gum Arabic	20.75	2.62	0.00	2.75	28.00
Aloe vera + Gum Arabic	21.05	2.78	10.00	3.50	28.00
Control (Untreated)	42.95	2.42	27.82	1.75	14.00
$FSLD_{(0.05)}$	0.21	0.13	4.12	0.57	NS

Table 3 shows the effect of variety and plant extracts on nutritional properties of sweet orange in Makurdi, Nigeria. TSS was significantly higher (P≤0.05) in Valencia compared with Washington while Vitamin C and pH were significantly higher (P≤0.05) in Washington compared with Valencia. There was no significant treatment effect on TA. Effect of plant extract showed that TSS was significantly higher (P≤0.05) in fruits treated with Aloe Vera and Aloe vera + Gum arabic compared with the control. Vitamin C content of fruits treated with Gum arabic was significantly (P≤0.05) higher followed by Aloe Vera + Gum Arabic compared with the control. All the treated fruits had significantly higher pH while TA was significantly lower (P≤0.05) compared with the control. The interaction of variety and plant extract on the nutritional properties of sweet orange is presented in Table 4. TSS was significantly higher (P≤0.05) when the fruits of Valencia were treated with each of the plant extract tested compared with the control. In the variety Washington, TSS was significantly higher (P≤0.05) when the fruits were treated with Aloe vera gel and with Aloe vera + Gum Arabic

compared with the control. The variety Valencia had significantly higher (P≤0.05) pH when treated with Gum Arabic while pH in Washington was significantly higher when the fruits were treated with Gum arabic and with Gum arabic + Aloe vera. There was no significant treatment effect on the vitamin C content. TA was significantly lowest (P≤0.05) in Washington treated with Gum Arabic except Valencia treated with Gum Arabic. The control treatment in Washington had the highest TA.

Correlation between the physical and nutritional qualities of the sweet orange fruits tested and % decay is presented in Table 5. Percent weight loss was positively and significantly correlated with % decay while marketability, shelf life, TSS, and TA were negatively and significantly correlated.

Table 2 Interaction effect of Variety and Plant extracts on some Physical qualities of sweet orange fruits after four (4) weeks of storage in Makurdi, Nigeria.

Variety	**Extracts**	**%Weight loss**	**Fruit firmness**	**% Decay**	**Marketability**	**Shelf life (days)**
Valencia	Aloe vera	21.0	2.60	6.20	5.50	21.00
	Gum Arabic	19.80	2.80	0.00	3.00	21.00
	Aloe vera + Gum Arabic	21.70	2.65	0.00	4.00	28.00
	Control	40.10	2.35	18.13	2.00	14.00
Washington	Aloe vera	20.70	2.60	10.00	4.50	28.00
	Gum Arabic	21.70	2.45	0.00	2.50	28.00
	Aloe vera + Gum Arabic	20.40	2.90	20.00	3.00	28.00
	Control	45.80	2.50	37.50	1.50	14.00
	$FSLD_{(0.05)}$	0.30	0.19	5.83	NS	NS

Table 3 Main effect of Variety and Plant extracts on Nutritional properties of sweet orange fruits after 4 weeks of storage in Makurdi, Nigeria

	TSS(0Brix)	**Vit C (mg.ml)**	**pH**	**TA**
Variety				
Valencia	9.75	30.87	3.90	0.68
Washington	9.41	32.69	4.11	0.62
Plant Extracts				
Aloe vera	10.00	30.82	4.07	0.67
Gum Arabic	9.50	34.05	4.12	0.51
Aloe vera + Gum Arabic	10.30	32.22	4.24	0.54
Control	8.50	30.01	3.60	0.93
FSLD(0.05)	0.06	1.55	0.46	0.65

Table 4 Interaction effect of Variety and Plant extracts on Nutritional properties of sweet orange fruits after four (4) weeks of storage in Makurdi, Nigeria**.**

Variety	Plant Extracts	TSS	Vit. C	pH	TA(%)
Valencia	Aloe vera	10.00	29.84	3.75	0.82
	Gum Arabic	10.00	33.07	4.17	0.54
	Aloe vera + Gum rabic	10.00	30.79	3.98	0.58
	Control	9.00	29.78	3.71	0.75
Washington	Aloe vera	10.00	31.81	4.39	0.39
	Gum Arabic	9.00	35.04	4.07	0.49
	Aloe vera + Gum rabic	10.60	33.66	4.51	0.51
	Control	8.00	30.24	3.49	1.11
	$FSLD_{(0.05)}$	0.09	NS	0.06	0.09

Table 5 Correlation Coefficient of the Physical and Nutritional properties of Orange fruit treated with Aloe vera and Gum Arabic with % fruit decay at 4 WAS

Parameters	% Fruit Decay
% weight loss	0.78**
Fruit firmness	-0.10
Marketability	-0.48*
Shelf life	-0.51*
TSS	-0.52**
Vitamin C	-0.43*
pH	-0.39
TTA	0.67*

4. Discussion

There was a decrease in the weight of the orange fruits at the end of the storage period. The minimum weight loss in the treated orange fruits may be due to retardation in the process of transpiration and respiration by closing of lenticels and stomata of the cell wall of the fruits. Weight loss increased in all the treatment with the advancement of the storage period, but was greater in the control at 4WAS. Padmaja and Don Bosco (2014) reported that fruits coated with *Aloe vera* gel had significantly less weight loss than those without coating also Martinez-Romero *et al.,* (2006) reported that *Aloe vera* gel coating was an effective physical barrier thereby reducing weight loss and lowering respiration rate during post-harvest storage of table grapes and cherries.

Total Soluble Solids (TSS) of the fruits increased during the storage period both for the coated fruits and the uncoated (control) fruits. In this study the uncoated (control) fruits recorded the lowest TSS value than the coated fruits. This contradicts the reports of Ergum and Satici (2012) who reported a decrease in TSS of tomato fruits coated with *Aloe vera* gel compared with the untreated control during storage. It is possible that species difference in the fruits used and the environmental conditions might have been responsible for this contradiction. In this study, the orange varieties showed significant difference on the TSS with Valencia having higher TSS compared with Washington. Similar findings by Liamngee *et al*., (2018) also reported varietal difference of tomato on total soluble solids (TSS) during storage.

The control (uncoated) fruits exhibited higher loss in firmness than the coated fruits at the end of the storage period. This may be due to the effects of the coating films which retards softening in the coated orange fruits. Orange fruits treated with the combination of *Aloe vera* gel and Gum Arabic gave firmer fruits at the end of the storage period than the control (untreated) fruits.

Reports by Chrysargyri *et al*. (2016) and Liamngee *et al*., (2018) showed that firmness of fruits decreases with increased in storage period. The Ascorbic acid content/vitamin C decreased with the advancement of the storage period in all the treatments. The highest vitamin C was recorded in the fruits treated with Gum Arabic at the end of the storage period. The decreasing trend in the vitamin C content may be probably due to the degradation of the ascorbic acid during the storage period. Lee and Kader (2000) and Ahmad *et al*., (2005) reported that coated fruits retained more vitamin C compared with uncoated fruits. The retention of the vitamin C in the coated fruits may be due to less degradation of the ascorbic acid in storage.

It was observed that both the coated and the uncoated fruits experienced an increase in pH at the end of the storage duration. However, the coated fruits had higher pH values than the uncoated (control) Athmaselvi ***et al***., (2013) reported that *Aloe vera* gel treated tomato fruits were better in keeping pH and showed a better effect in comparison with untreated fruits. The higher acidity in treated fruits observed in this study might be because of reduced respiration rate due to limited availability of oxygen (Jiang and Li, 2001). Titratable acidity of the fruits decreased during the storage period. Titratable acidity (TA) of Valencia fruit was higher than that of Washington fruits. This could be as a result of the concentration of the organic acid present in the Washington variety. The decreasing acidity at the end of storage might also be due to the metabolic changes in fruits resulting from the use of organic acids in respiratory process. Wijewardane and Guleria (2013) have reported a decline in TA for stored apples coated with Neem oil.

The plant-based extracts lowered decay of orange fruits in both Washington and Valencia fruits. Untreated orange fruits showed higher decay in storage. There was no decay loss in fruits coated with Gum Arabic in both Washington and Valencia fruits. This effect may be due to the activity of phytochemicals present in the extracts (alkaloids, terpenoids, resin, phenols, glycosides, saponins and phlobaamin) contributing to reduction of activities of pathogenic agents that cause decay (Ref) Similar findings was reported by Liamngee *et al.,* (2019) who showed that the use of aqueous *Moringa* leaves extracts reduced fruit decay caused by fungal pathogens in tomatoes during storage.

The marketable value of orange fruits was lowest in the untreated control. The loss of firmness and increased decay during storage in the untreated fruits contributed to the low marketability of the fruits. Valencia fruits in this study produced higher values of marketable fruits than Washington Liamngee *et al*., (2018) similarly reported that, 100% *Aloe vera* coating produced the highest marketable value than those treated with 0% irrespective of the variety. The ability of the coating film to maintain the marketable value of the orange fruits may be due to the the films forming a protective layer on the fruits thereby preventing oxygen and moisture loss and reducing entry of pathogenic agents.

The longest shelf life (28days i.e. 4WAS) was recorded in orange fruits preserved with plant-based extracts compared with the lowest shelf life (14days i.e. 2WAS) recorded in the untreated fruits. This may be due to their capacityof Aloe vera and Gum arabic to reduce postharvest decay. Maftoonazad and Ramaswamy (2008), Mandal *et al;*(2018) and Liamngee *et al*;(2018) reported that avocadoes and tomatoes coated with plant-based extracts had longer shelf life (26.33days and 25 days) whereas lower shelf life (22days and 21 days) was recorded in untreated fruits respectively.

5. Conclusion

The results of this study have established that plant extracts of *Aloe vera* gel and Gum Arabic possess ability to improve the physical properties of fruits in storage. The extracts also have the ability to increase the shelf life and maintain the physicochemical quality of orange fruits during storage.These plant extracts are not only environmentally friendly, easy to produce and easy to apply formulations, they are also safe for consumers and provide alternative means for maintaining postharvest physiology and management of crops. However, orange variety also significantly determined the extent of change. Among the orange varieties studied, Washington gave better shelf life and physiological quality during storage. We therefore recommend the use of combination of *Aloe vera* gel and Gum Arabic extracts for the storage of orange varieties.

Compliance with ethical standards

Disclosure of conflict of interest

Authors have declared that no competing interests exist

Author's Contribution

This work was carried out in collaboration between all authors. Author LBA conducted laboratory experiments, recorded laboratory observations, wrote the protocol and wrote the first draft of the manuscript. Author EJE conceived the idea and supervised the experiments, and review the manuscripts making constructive criticism.. Author KL managed the analyses of the study and advised the laboratory technique. Author TRU managed the literature searches and perform data analysis. All authors read and approved the final manuscript

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