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Postharvest physicochemical properties of cucumber fruits (*Cucumber sativus* L) treated with chitosan-lemon grass extracts under different storage durations

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The present study was carried out to evaluate the effects of chitosan-based edible coatings with lemon grass extract on the physical properties and overall acceptability of cucumber fruits stored at ambient temperature (28 ± 2°C) and 85 to 90% relative humidity for 14 days. Blends of chitosan (C) and lemon grass extract (E) were formulated as 0.5% C + 0.5% E, 0.5% C + 1% E, 1% C + 0.5% E and 1% C + 1% E. Fresh cucumber fruits were treated with the blends, while the untreated cucumber was used as the control. Physical quality parameters (weight loss, fruit firmness, colour using chromameter, and diameter) of the fruits were assessed on weekly basis during storage. The fruits were subjected to sensory evaluation after 14 days of storage using 20 member preference panel. After 14 days, weight loss was 1% for cucumber fruits treated with 1.0% C + 1.0% E, and 4% for control untreated fruits. No significant difference (P < 0.05) was observed in the firmness of all the treated cucumber fruits after 14 days, while the untreated significantly reduced by 4%. External colour analysis of L*a*b* parameters showed no significant change in L* (lightness) and a* (green to red) with the storage time (14 days) in treated fruits. However, values of b* (blue to yellow) changed significantly (*p*< 0.05) after 14 days in untreated control cucumber fruits. All fruits significantly decreased in diameter with days of storage; except for 1.0% C + 1.0% E treated cucumber fruits, which showed no further decrease after 7 days of storage. No significant difference was observed in the taste, pulp and peel colour, texture, flavour as well as the overall acceptability of stored cucumber fruits but the control sample was rated higher in overall acceptability. In this study, the combination of chitosan and lemon grass extract, especially 1.0% C +1.0% E as an edible coating, has proved to have great potential to preserve the physical characteristics of cucumber fruits at ambient temperature 28 ± 2°C peculiar to tropical countries. This combination gave better physical parameter results.

Key words: Edible coatings, cucumber, lemon grass extract, chitosan, physical properties, overall acceptability.

INTRODUCTION

The problem of postharvest losses of fruits in the tropics is of great concern to farmers, fruit-traders and consumers. In some African, Caribbean and Pacific ACP countries, where tropical weather and poorly developed infrastructure contribute to the problem, wastage can regularly be as high as 40 to 50% (SPORE, 2011). Factors responsible for postharvest losses especially in the tropics are decay, mechanical damage, physiological

disorders, action of fruit flies, during harvest, storage and transport. The use of controlled atmosphere storage and modified atmosphere storage in reducing the postharvest losses were in practice until the introduction of edible coating. The use of edible coatings is on the increase owing to their safety regarding consumption and their environmentally friendly nature in terms of application. The system by which edible coatings extend the shelf life of fruits and vegetables is through the establishment of a modified atmosphere around the product, which serves as a partial barrier to O_2 and CO_2, water vapor and aromatic compounds, decreasing the respiration rate of the fruit and water loss and preserving texture and flavor (Olivas and Barbosa - Canovas, 2005). Presently, examples of coating materials in use are polysaccharides such as cellulose derivatives, starch, chitin, and gums, proteins which include soya protein, milk, gelatin, corn, zein, and wheat gluten; and lipids such as oils, waxes, and resins (Ramos-García et al., 2010).

Chitosan, a polysaccharide which composed of β-(1-4)-D-glucosamine and β-(1-4)-N-acetyl-D-glucosamine, is obtained by alkaline deacetylation of chitin. The chemical structure of chitosan is close to that of cellulose and it protects perishable foods from deterioration by reducing dehydration, respiration, and maintaining the textural quality (No et al., 2007). Previous researches had shown that application of chitosan coating improved the storability of several perishable fruits, such as strawberry, tomato, litchi, longan (Jiang and Li, 2001, Gonzalez-Aguilar et al., 2010). Chitosan has wide range of applications in various fields, like waste management, food processing, nanotechnology, medicine and biotechnology. Its application in pharmaceutical industry is due to its low toxicity, biodegradability and biocompatibility (Shiekh et al., 2013). It is a natural polycation compound with antifungal activity (Liu et al., 2007), capable of inducing host resistance to pathogens (Trotel-Aziz et al., 2006). Its ability to create a semi-permeable film on fruit surface (Bautista-Banos et al., 2006) has made it to be a natural potential fungicide in postharvest storage. The biological activity of chitosan is influenced by its molecular weight, degree of deacetylation and derivatisation, such as degree of substitution, length, and position of a substitute in glucosamine units of chitosan, pH of chitosan solution and the target organisms.

The use of edible coatings in conjunction with low temperature storage has been reported to be a promising approach to minimize storage problems and to preserve the freshness of fruits and vegetables, especially tomatoes (Gonzalez-Aguilar et al., 2010). This might not be practicable in developing countries where there is epileptic electrical or power supply. Plant extracts have been reported to have antimicrobial properties and could inhibit spore formation, mycelia growth (Bautista-Baños et al., 2000). *Cymbopogon citratus* (Lemon grass) is a monocotyledonous aromatic perennial plant (Inouye et al., 2000), commonly planted in backyard gardens in Nigeria. Phytochemical investigation by Asaolu et al. (2009) revealed the presence of alkanoids, saponins, flavonoids, tannins, anthraquinones, steroids and phenols in Lemon grass extract. Extracts of its leaves are used in traditional medicine as antimicrobial, anti-inflammatory and sedative. The leaf essential oil is used in the food, perfumery, soap, cosmetic, pharmaceutical and insecticide industries. However, the combined effect of chitosan and plant extracts might be a useful postharvest technique in extending the shelf-life and preserving the qualities of fruits and vegetables in the developing countries.

Cucumber fruit (*Cucumis sativus* L) are cultivated in subtropical and tropical environments and are therefore native to many countries of the world (Gross et al., 2014). The consumption of fresh cucumber fruit provides a range of health benefits including valuable antioxidant, anti-inflammatory, and anti-cancer benefits (Mukherjee et al., 2013). The worldwide production of cucumber was 65 million tonnes in 2012, grown in an area of 2,109,650 ha (FAOSTAT, 2013). Cucumber is a highly perishable crop and the environmental conditions under which cucumber is produced, transported and displayed have a noteworthy effect on its keeping quality and loss (Cortbaoui and Ngadi, 2015). In most Sub - Saharan countries such as Nigeria, cucumber fruits are often kept and displayed on the shelves in market places, resulting in degreening, and other physiological deterioration associated with alterations in the nutritive values and quality parameters.

This study was undertaken to investigate the applicability of combined formulation of chitosan and ethanolic extract of lemon grass at varied concentration on the physical properties and overall acceptability of cucumber fruits stored at ambient temperature, as this will assist local stores in keeping cucumber fruits in good condition before sale.

MATERIALS AND METHODS

Immature cucumber (C*ucumis sativus* L.) fruits were harvested in June, 2015, from the Teaching and Research Farm of The Federal University Technology, Akure, Nigeria. The fresh fruits were handpicked for uniformity in size and shape, and absence of external injury. These were washed with chlorinated water (0.05% NaOCl), rinsed with distilled water and allowed to air dry (Ali et al., 2015).

Fresh leaves of lemon grass were also harvested within the staff quarters of The Federal University Technology, Akure, Nigeria.

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Chitosan, 90% deacetylation degree, low molecular weight was obtained from BioChemika, Sigma-Aldrich, Steinham, Switzerland, Tween 80 were obtained from Acros Organics (Belgium); ethanol absolute from Chem-lab NV (Belgium). All other reagents were of analytical grade.

Production of lemon grass extract

The lemon grass extract (E) was produced as described by Uzama (2009). Leaves were washed and air dried in the laboratory for two weeks, they were grounded using an Excella mixer grinder and sieved with a mesh of size 0.5 mm. Fifty grammes of the powdered leaves (50 g) was placed in a 500 ml conical flask, 250 ml of ethanol was added and stirred vigorously using a magnetic stirrer. This was allowed to stand for 36 h after which it was filtered. The extract was concentrated using a rotary evaporator to 50 ml, cooled and stored in McCartney bottles at 4°C until use.

Production of chitosan solution

Chitosan (C) solutions of concentrations 0.5% and 1.0% (w/v) were prepared. For 0.5% chitosan solution, 5 g of chitosan was dissolved in 1 L of distilled water (60°C) containing 10 ml of glacial acetic acid with the aid of magnetic stirrer for 5 h, while for 1.0% chitosan solution, 10 g of chitosan was dissolved in 1 L of distilled water (60°C) containing 10 ml of glacial acetic acid with the aid of magnetic stirrer for 5 h. The pH of the solution was adjusted to 5.6 to 5.9, by 1 N NaOH as described by Ali et al. (2015).

Preparation and application of chitosan - lemon grass extract coating

Chitosan - lemon grass extract coating were formed from the blends of C and E by blending 0.5% C and 0.5% E; 0.5% C and 1.0% E; 1.0% C and 0.5% E; 1.0% C and 1.0% E. Previously cleaned and chlorinated (0.05%) washed cucumber fruits were dipped for 5 min into the respective coatings, after which they were air dried for 2 h at room temperature. They were stored on shelves at ambient room temperature of 28 ± 2°C and 85 to 90% relative humidity for 14 days, during which quality parameters were analyzed.

Physical properties of cucumber in storage

Weight loss of cucumber in storage

Cucumber fruits were weighed using a mechanical weighing scale (CAMRY; SQ; China) at the beginning of the experiment (Wi) and at every 7 days during storage till the end of the storage period (Wf). The results were expressed as the percentage loss of initial weight.

$$\%\ weight\ loss = \frac{\text{Initial weight (Wi)} - \text{Final weight (Wf)}}{\text{Initial weight (Wi)}} \times 100 \quad (1)$$

Firmness of cucumber in storage

The fruits firmness was measured at the equatorial region using an Instron-Universal Testing Machine (Model 4411, Instron, Massachusetts, USA). A plunger with diameter of 6 mm was used to puncture the fruits tissues to a depth of 5 mm for the determination of firmness at a crosshead speed of 150 mm/min using a 50 N load cell. Three fruits per replication, each punctured on both sides, were subjected to firmness testing.

Colour of cucumber in storage

The colour of fruits was evaluated on the storage shelves using Chromameter (Model WSC-S, Shanghai Precision and Scientific Instrument Co., Ltd., Shanghai, China). L* value (lightness), a* value (greenness), and b* value (yellowness) of the cucumber samples were recorded. Measurements were taken on four samples and the average of L*, a*, and b* values were recorded.

Diameter of cucumber in storage

The diameter was measured using a digital Vernier caliper (Model TESA 1p65- Range 0-150 mm ± 0.01 mm, Swiss).

Chemical properties of cucumber in storage

Titratable acidity of cucumber in storage

Titratable acidity was determined using 942.15 AOAC methods (AOAC, 2005). Ten grams (10 g) of each treated cucumber was homogenized using a kitchen blender with 100 ml of distilled water. The mixture was filtered through a filter paper and 10 ml of the filtrate was pipetted and titrated against 0.1 mol L^{-1} NaOH to phenolphthalein end-point. Results were expressed as % (grams of citric acid equivalent per100 g of cucumber).

Soluble solids (SS) of cucumber in storage

Soluble solid content (°Brix) of homogenized fruits was determined using a hand refractometer (Reichert, Scientific Instruments, China).

Sensory evaluation and overall acceptability of cucumber after storage

Fruits were subjected to sensory evaluation after 14 days of storage. Preferences for external and internal fruits appearance, edible quality, and overall fruit preference were recorded for each of the grouped cucumber (treated and untreated) by an untrained, 20-member preference panel. The panelists were randomly selected from staff and students of the University community. A nine (9) point hedonic scale was used to rate taste, peel colour, texture and flavour and overall fruits preference. The scale was labeled from 1 to 9 where 1 represents dislike extremely and 9 represent like extremely.

Statistical analyses

Data were statistically analysed using one - way Analysis of variance (ANOVA) and Tukey post-hoc at a pre-set significance level of 0.05. All statistical analysis was done using computer program (SAS, version 8.0, SAS Institute, Cary, NC, USA).

RESULTS AND DISCUSSION

Weight loss of cucumber fruits

Figure 1 revealed a significant difference (p<0.05) in the weight loss of treated and control cucumber fruits in storage. Cucumber fruits treated with 1%C +1%E had the

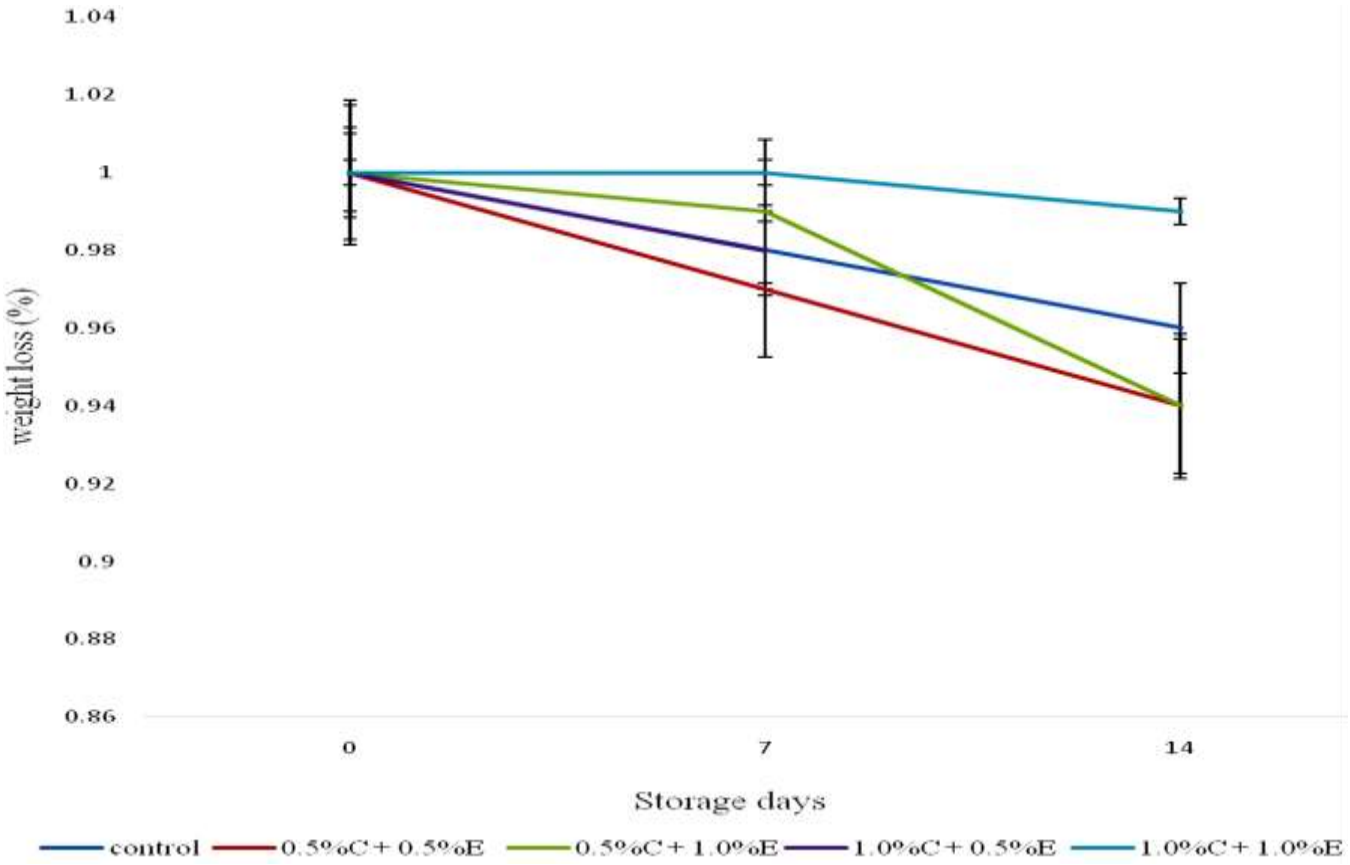

Figure 1. Weight loss of cucumber fruits (%) in different duration treated by chitosan-lemon grass extracts of different concentartion. Control, Untreated cucumber fruits; 0.5%C + 0.5%E, cucumber fruits treated with 0.5% Chitosan - 0.5% Lemon grass extract; 0.5%C + 1%E, cucumber fruits treated with 0.5% Chitosan - 1% Lemon grass extract; 1%C + 0.5%E, cucumber fruits treated with 1% Chitosan - 0.5% Lemon grass extract. 1%C + 1%E, cucumber fruits treated with 0.5% chitosan - 0.5% lemon grass extract.

lowest weight loss (1%) after 14 days. The highest weight loss (6%) was observed in cucumber fruits treated with 0.5%C + 0.5%E followed by the control cucumber (4%). Loss of weight in fresh fruits and vegetables is mainly due to the loss of water caused by transpiration and respiration processes (Zhu et al., 2008). Percentage weight loss of cucumber fruits decreased with increasing concentrations of chitosan and lemon grass extract coatings. The low weight loss (%) observed in 1%C + 1%E implies that the blends of chitosan - lemon grass coating especially at 1% concentration each, provides barrier against diffusion of O_2, CO_2, moisture and solute movement, thereby reducing respiration, water loss and oxidation reaction rates through the stomata. Chitosan has been reported to be more effective at delaying weight loss in banana and mango (Kittur et al., 2001) and strawberries (Ribeiro et al., 2007). This also agrees with the findings of Dong et al. (2004), that chitosan coating forms a semi-transparent layer on smooth surface which reduces respiration and transpiration rates through fruit surfaces. Cucumber fruits are not easily prone to weight loss because of its thick skin, however, Kang et al. (2002), had reported 7% weight loss during storage as the limit of marketability for cucumber appearance. Weight loss obtained in this study for all treatment concentrations was less than 7% which favours the use of chitosan and lemon grass extract blend coating, in postharvest storage of cucumber.

Firmness of cucumber of fruits

The fruits firmness, an attribute that indicates the shelf life and quality of fruit is presented in Table 1. No significant ($P \geq 0.05$) reduction was observed in firmness of fruits treated with 1%C + 1% E, 0.5%C + 1%E as well as 0.5%C + 0.5% E within the 14 days of storage. The control cucumber fruits showed a significant ($p \leq 0.05$) reduction in firmness as storage days proceeds. This agrees with the findings of Thommohaway et al. (2007) on the firmness of fresh-cut guava coated with chitosan and Bautista-Banos et al. (2003), in solo papayas treated

Table 1. Firmness (N) of cucumber stored at ambient temperature.

Storage (days)	0	7	14
Control	52.5 ± 0.81[a]	50.6 ± 0.55[b]	50.3 ± 0.13 [b]
0.5%C+0.5%E	55.2 ± 0.10[a]	53.2 ± 1.91[a]	54.2 ± 0.10[a]
0.5%C+1%E	50.7 ± 0.70[a]	50.2 ± 0.10[a]	50.1 ± 0.10[a]
1%C+0.5%E	50.5 ± 0.16[b]	50.5 ± 0.65[b]	52.2 ± 0.12[a]
1%C+ 1%E	51.0 ± 0.37 [a]	51.2 ± 0.87[a]	50.3 ± 0.10[a]

Values represent means of triplicate (n=3) separated using Duncan multiple range test (DMRT) at $p \leq 0.05$. Values with the same alphabet along the same row are not significantly different ($p \leq 0.05$).Control, untreated cucumber fruits. 0.5%C + 0.5%E, cucumber fruits treated with 0.5% Chitosan - 0.5% Lemon grass extract; 0.5%C + 1%E, cucumber fruits treated with 0.5% chitosan -1% Lemon grass extract; 1%C + 0.5%E, cucumber fruits treated with 1% chitosan - 0.5% lemon grass extract; 1%C + 1%E, cucumber fruits treated with 0.5% Chitosan -0.5% lemon grass extract.

with 1.5% chitosan coating. The positive outcome of high chitosan concentration on firmness has also been reported for 'Murcott' tangor (Chien et al., 2007), papaya (Ali et al., 2011) and guava (Keqian et al., 2012). Fruit softening is due to weakening in the cell structure, the cell wall composition and the intracellular materials (Shiekh et al., 2013). It is a biochemical process involving the hydrolysis of pectin and starch by enzymes, such as wall hydrolases. The combination of chitosan and lemon grass extract coatings at the concentrations under study might have inhibited the activities of the enzyme hydrolase thereby maintaining the firmness of the fruit. Similarly, the maintenance of fruits firmness might be attributed to the high antifungal activity of the coating and its ability to cover of the cuticle and lenticels, thereby reducing infection, respiration and other ripening processes during storage (Martínez-Romero et al., 2006). Firmness is an important factor that affects the quality and consumer acceptability of fresh fruits.

Colour of cucumber

The color changes in cucumber skin as influenced by storage time and treatment with chitosan and lemon grass extract is shown in Table 2. There was no significant change ($p \geq 0.05$) in lightness (L*) values of the fruits treated with 0.5% C + 0.5%E, 0.5% C + 0.5%E, 1%C + 0.5%E and control fruits during the period of storage (14 days). Similarly, no significant differences ($p \geq 0.05$) was observed between the (greenness) a* and yellowness (b*) values of the treated and control fruits as the storage days progresses. This contradicts the findings of Phal Sargent and Maynard (2013), who observed that the peel colour of uncoated cucumber remained dark green only within 6 days of storage at ambient temperature. In freshly harvested green vegetables, yellow carotenoids coexist with green chlorophylls. During ripening of fruits, chlorophyll constantly decreases, exposing the lighter yellow pigments, also if stored for a long time, most green vegetables will undergo eroding of chlorophyll (Moalemiyan and Ramaswamy, 2012), which shortens its shelf life and affects quality (Fukasawa et al., 2010). It therefore implies that in this study, the storage days employed were not enough for senescence to set in, also the respiration rate of the species of cucumber fruits used might be slow which invariably slows down ripening in both the treated and control cucumber fruits.

Diameter of cucumber

Figure 2 shows the effect of chitosan and lemon grass extract coating on the diameter of cucumber fruits stored at ambient temperature. There were no significant decrease ($p \geq 0.05$) in the diameters of the treated and control cucumber fruits. Decrease (1%) was observed in the diameter of 1%C +1%E treated cucumber fruits on day 7 of storage and remained constant through the storage period. All the other treatments including the control showed a decrease in diameter on day 14 of storage. Bart-Plange and Baryeh (2003) reported that the diameter of a fruit is a measure that judges its normal and healthy growth. The observation agrees with the findings of Nadim et al. (2015), where no significant difference ($p \geq 0.05$) was observed in the diameter of strawberry coated with methylcellulose-based edible coating and the control. Decrease in diameter of fruits is usually caused by water loss which is as a result of transpiration and respiration resulting in the shrivelling of fruits (Hazbavi et al., 2015). The observed weight loss in this study was not significant enough to bring about significant decrease in the diameter of the treated and untreated control samples.

Titratable acidity of cucumber

The titratable acidity (TA) values of chitosan and lemon grass extract treated and untreated samples during storage decreased with storage time (Table 3). At the end of the storage, highest percentage decrease (42%) of TA

Table 2. Colour of cucumber.

Storage (days)	0	7	14
L*			
Control	56.7±0.70^{a}	54.8±0.60^{b}	56.7±0.10^{a}
0.5%C+0.5%E	63.0±1.75^{a}	62.5±0.03^{a}	62.5±0.13^{a}
0.5%C+1%E	61.0±1.19^{b}	62.1±0.01^{ab}	62.6±0.10^{a}
1%C+0.5%E	62.3±0.81^{a}	60.2±0.03^{b}	61.5±0.10^{a}
1%C+1%E	61.9±0.26^{b}	62.7±0.03^{a}	62.6±0.11^{a}
a*			
Control	-49.2±0.43^{a}	-48.8±0.49^{a}	-49.0±0.09^{a}
0.5%C+0.5%E	-59.5±0.60^{a}	-59.2±0.02^{a}	-59.3±0.14^{a}
0.5%C+1%E	-57.9±0.85^{b}	-58.4±0.05^{ab}	-59.3±0.08^{a}
1%C+0.5%E	-58.9±0.68^{a}	-58.2±0.02^{a}	-58.4±0.08^{a}
1%C+1%E	-58.1±0.43^{b}	-59.0±0.67^{ab}	-59.5±0.09^{a}
b*			
Control	11.0±0.09^{a}	10.7±0.54^{a}	10.0±0.01^{b}
0.5%C+0.5%E	10.4±0.82^{a}	10.6±0.02^{a}	10.5±0.06^{a}
0.5%C+1%E	9.9±0.20^{b}	9.3±0.15^{c}	10.6±0.09^{a}
1%C+0.5%E	9.3±0.14^{b}	9.4±0.07^{b}	10.4±0.07^{a}
1%C+1%E	9.9±0.91^{a}	9.53±0.52^{a}	10.7±0.09^{a}

Values represent means of triplicate (n=3) separated using Duncan multiple range test (DMRT) at $p \leq 0.05$. Values with the same alphabet along the same row are not significantly different ($p \leq 0.05$). Control, Untreated cucumber fruits; 0.5%C + 0.5%E – Cucumber fruits treated with 0.5% chitosan- 0.5% lemon grass extract; 0.5%C + 1%E, Cucumber fruits treated with 0.5% chitosan- 1% lemon grass extract; 1%C + 0.5%E, cucumber fruits treated with 1% chitosan - 0.5% lemon grass extract; 1%C + 1%E, Cucumber fruits treated with 0.5% chitosan - 0.5% lemon grass extract

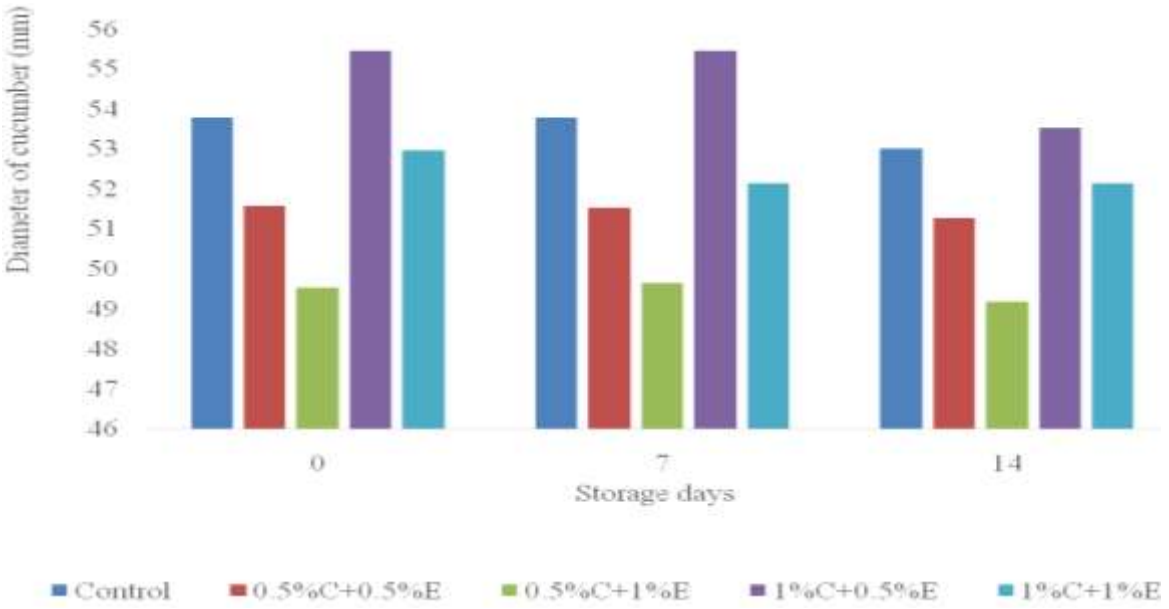

Figure 2. Diameter of Cucumber fruits (mm) in different duration treated by chitosan-lemon grass extracts of different concentration. Control, Untreated cucumber fruits; 0.5%C + 0.5%E, cucumber fruits treated with 0.5% chitosan - 0.5% lemon grass extract; 0.5%C + 1%E, cucumber fruits treated with 0.5% chitosan - 1% lemon grass extract; 1%C + 0.5%E, cucumber fruits treated with 1% chitosan -0.5% lemon grass extract; 1%C + 1%E, cucumber fruits treated with 0.5% chitosan -0.5% lemon grass extract.

Table 3. Titratable acidity (%) of cucumber.

Storage (days)	0	7	14	% decrease
Control	0.36±0.01^{a}	0.22±0.02^{b}	0.21±0.04^{b}	42
0.5%C+0.5%E	0.39±0.01^{a}	0.29±0.021^{b}	0.25±0.02^{c}	36
0.5%C+1%E	0.34±0.01^{a}	0.25±0.01^{b}	0.23±0.02^{c}	32
1%C+0.5%E	0.31±0.03^{a}	0.28±0.01^{b}	0.23±0.01^{c}	26
1%C+ 1%E	0.29±0.01^{ab}	0.30±0.03^{a}	0.25±0.01^{b}	14

Values represent means of triplicate (n=3). Values with the same alphabet along the same row are not significantly different ($p \leq 0.05$); Control, Untreated cucumber; 0.5% C + 0.5% E, cucumber treated with 0.5% Chitosan - 0.5% Lemongrass extract; 0.5% C + 1% E, cucumber treated with 0.5% chitosan - 1% lemongrass extract; 1% C + 0.5% E, cucumber treated with 1% chitosan -0.5% lemongrass extract; 1% C+ 1% E, cucumber treated with 1% chitosan -1% lemongrass extract.

Table 4. Total soluble solids (^{o}Brix) of cucumber.

Storage (days)	0	7	14	% Decrease
Control	3.0 ± 0.01^{b}	3.2 ± 0.01^{a}	2.8± 0.01^{c}	7
0.5%C+0.5%E	3.9 ± 0.01^{b}	4.2 ± 0.02^{a}	3.2 ± 0.01^{c}	18
0.5%C+1%E	3.9 ± 0.01^{b}	4.0 ± 0.01^{a}	3.4 ± 0.02^{c}	12
1%C+0.5%E	3.9 ± 0.02^{b}	4.8 ± 0.03^{a}	3.0 ± 0.01^{c}	23
1%C+ 1%E	3.9 ± 0.01^{b}	4.0 ± 0.01^{a}	3.0 ± 0.01^{c}	23

Values represent means of triplicate (n=3). Values with the same alphabet along the same row are not significantly different ($p \leq 0.05$); Control, Untreated cucumber; 0.5% C + 0.5% E, cucumber treated with 0.5% Chitosan - 0.5% Lemongrass extract; 0.5% C + 1% E, cucumber treated with 0.5% chitosan - 1% lemongrass extract; 1% C + 0.5% E, cucumber treated with 1% chitosan -0.5% lemongrass extract; 1% C+ 1% E, cucumber treated with 1% chitosan -1% lemongrass extract.

was observed in the untreated cucumber fruits, as the TA decreased from 0.36 to 0.21%. The least percentage decrease was observed in 1% C + 1% E (14%). This further corroborates the fact that 1%C + 1%E delayed ripening by providing a semi-permeable film around the fruit and therefore reduced the metabolic rate of the treated fruits (Ibrahim et al., 2014). It also agrees with the observation of Ali et al. (2015), where the combination of essential oil with chitosan treatments on bell pepper maintained significantly higher values for TA as compared to the control.

Decline in TA is an important event during ripening, as it renders the fruit less acidic and sour. Since organic acids, such as malic or citric acid, are primary substrates for respiration, a reduction in acidity is expected in respiring fruits. According to Hong et al. (2012), the faster the reduction in acidity the faster the senescence. Higher concentration of chitosan and lemon grass extract on cucumber fruits might therefore reduce the rate of respiration and delay the utilization of organic acids which will result in lower loss of acidity in cucumber fruits.

Total soluble solids of cucumber

The total soluble solids (TSS) shown in Table 4 revealed an increase and a later decrease of the soluble solids in the chitosan and lemon grass extract treated cucumber fruits as well as the untreated samples during the storage period. The increase was significant from day 0 to day 7 while the decrease was significant on day 14 for both treated and the control cucumber fruits. This agrees with the report of Moalemiyan and Ramaswamy (2012) where an increase in TSS of cucumber fruits (coated and control) was observed from 0 to 10 days, then a decrease up to day 15. Also, Nadim et al. (2015) noted that the total soluble solids of strawberry fruits coated with methylcellulose-based edible coating increased up to day 7, and then decreased to the end of storage. Similar results were recorded for tomato (Ali et al., 2011) and for banana fruits coated with cellulose edible coatings (Jafarizadeh et al., 2011).

The increase in TSS observed during storage might be due to the breakdown of starch into simple sugars. In general, sugars are the primary constituents of soluble solid concentration of a product which are consumed during respiration. Decreased respiration rates slow down the synthesis and use of metabolites and this result in lower TSS due to the slower hydrolysis of carbohydrates to sugars (Yaman and Bayoindirli, 2002). In this study, higher TSS values were observed in all the treated samples with chitosan and lemon grass extract than in

Table 5. Sensory evaluation of cucumber after storage.

Concentration	Taste	Peel colour	Pulp colour	Texture	Flavour	Overall acceptability
Control	7.0 ± 1.34[a]	7.5 ± 1.27[a]	7.8 ± 1.34[a]	7.7 ± 1.40[a]	6.9 ± 1.31[a]	7.4 ± 1.33[a]
0.5%C+ 0.5%E	7.1 ± 1.31[a]	7.3 ± 1.07[ab]	7.4 ± 1.15[a]	7.5 ± 1.03[a]	6.9 ± 1.06[a]	7.2 ± 1.12[a]
0.5%C+1%E	7.1 ± 1.54[a]	7.7 ± 1.32[a]	7.5 ± 1.27[a]	7.4 ± 0.96[a]	7.0 ± 0.89[a]	7.3 ± 1.20[a]
1%C+0.5%E	7.0 ± 0.97[a]	6.8 ± 0.98[ab]	7.2 ± 1.11[a]	7.3 ± 0.95[a]	6.8 ± 1.00[a]	7.0 ± 1.00[a]
1%C+1%E	6.7 ± 1.20[a]	6.7 ± 1.21[b]	7.1 ± 1.39[a]	7.2 ± 1.22[a]	6.9 ± 0.88[a]	6.9 ± 1.18[a]

Values represent means of triplicate (n=3). Values with the same alphabet along the same row are not significantly different (*p≤0.05*); Control, Untreated cucumber; 0.5% C + 0.5% E, cucumber treated with 0.5% Chitosan - 0.5% Lemongrass extract; 0.5% C + 1% E, cucumber treated with 0.5% chitosan - 1% lemongrass extract; 1% C + 0.5% E, cucumber treated with 1% chitosan -0.5% lemongrass extract; 1% C+ 1% E, cucumber treated with 1% chitosan -1% lemongrass extract.

the untreated samples.

Sensory evaluation of cucumber after storage

The sensory evaluation of cucumber fruits treated and untreated with chitosan and lemon grass extract at the end of storage were summarized in Table 5. No significant difference *(p≥0.05)* was observed in pulp colour, peel colour, texture, flavor assessed for treated and untreated cucumber fruits at the end of day 14. The untreated fruits were as acceptable as those treated with chitosan and lemon grass extracts to the panelists. This agrees with the report of Yahia et al. (2008) who reported that cucumber can be stored for two weeks. But it was in contrast with the result obtained by Al-Juhaimi et al. (2012) who reported a significant difference (*p≤ 0.05)* between 20% gum Arabic coated and uncoated cucumber fruit. In cucumber fruits, the main signs of aging and deterioration in quality are yellowing and shrivelling as a result of water loss (Zapotoczny and Markowski, 2014), but these were not observed in the chitosan and lemon grass extract treated fruits as well as the control untreated fruits on day 14 of storage. No significant difference *(p≥0.05)* was observed in the overall acceptability of both treated and untreated cucumber fruits.

Conclusions

In this study, the combination of chitosan and lemon grass extract, especially 1.0% C +1.0% E as an edible coating, has proved to have great potential to preserve the physical characteristics of cucumber fruits at ambient temperature 28 ± 2°C peculiar to tropical countries. This combination gave better physical parameter results. The coating of cucumber fruits with 1%C + 1%E was the most effective of the treatments in reducing weight loss, firmness and titratable acidity. Treatment had no significant effect on the length, diameter, colour and total soluble solids of cucumber fruits during the 14 days of storage. Similarly, no significant difference (p≥0.*05*) was observed between the sensory attributes considered in treated and untreated cucumber fruits, which implies that reduction in weight loss, firmness and titratable acidity observed, were not sufficient to make an observable change in the sensory attributes of the cucumber fruits. Storage days of more than 14 days may have shown differences between the treated and untreated cucumber fruits.

Conflicts of Interests

The author has not declared any conflict of interests.

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