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RESEARCH ARTICLE

Combination of Chitosan and Lemongrass (*Cymbopogon citratus*) Essential Oil as Edible Coating to Cantaloupe (*Cucumis melo* L) Quality and Shelf Life during Storage

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Abstract

Cantaloupe (*Cucumis melo* L.) is an important source of bioactive compounds, which are considered to be health beneficial. Chitosan and its derivatives have a wide range of applications, for example thickening, film formation, metal binding and antimicrobial activity. Lemongrass (*Cymbopogon citratus)* contains various phytoconstituents such as flavonoids and phenolic compounds, terpenoids and essential oils, which may be responsible for the different biological activities. The objective of this study was to evaluate the combination of chitosan with lemongrass essential oil as edible coating to improve the quality and extend the shelf life of Cantaloupe (*Cucumis melo* L.) during storage. Cantaloupe fruits were coated in different formulas of chitosan: lemongrass essential oil (0.15%: 0.15%, 0.20%: 0.1%, 0.25%: 0.05%, respectively). The uncoated fruits were used as control samples. Then, cantaloupe fruits were preserved at ambient temperature (28°C) and cool storage (4°C). The effectiveness of edible coating in cantaloupe fruit quality and shelf life was evaluated by estimating weight loss, firmness, total soluble solids, total acidity, ascorbic acid, carotenoid content, microbial proliferation (total bacterial, yeast and mold) and sensory acceptability at beginning and during 16 days of storage. The results obtained showed that 0.20%: 0.1% (chitosan: lemongrass essential oil) as edible coating could reduced weight loss; maintained firmness, total soluble solids, total acidity, ascorbic acid and sensory score; delayed the change in cartenoid content and microbial proliferation. The coated fruits had a shelf life of 16 days (4^{o}C) or 12 days (28^{o}C) under storage.

Keywords: *Cantaloupe, Chitosan, lemongrass essential oil, Coating, Shelf life.*

Introduction

Coating films can act as barriers to moisture and oxygen during processing, handling and storage [1]. Moreover, they can retard food deterioration by inhibiting the growth of microorganisms, due to their natural intrinsic activity or to the incorporation of antimicrobial compounds [2]. Chitosan has been wide range if applications in various fields, like waste management, food processing, nanotechnology, medicine and biotechnology.

Chitosan is very interesting material in food applications due to its low toxicity, biodegradability and biocompatibility. Chitosan, as a natural polycation compound with antifungal activity [3,4] capability for induction of the host resistance to pathogens (Trotel-Aziz et al., 2006) and ability to create a semi-permeable film on fruit surface [3,5] has been proven to be a natural potential fungicide in postharvest fruit. It has been reported that postharvest application of chitosan coating has a good control effect on decay of grapes [6, 7]. Chitosan, a natural biopolymer has been reported to enhance resistance against many fungal diseases including *Penicillium digitatum*, *Penicillium italicum* of fruits and vegetables when applied as either a pre- or postharvest treatment [8].

Chitosan can be directly antimicrobial and has been shown to interfere with the germination and growth of several phytopathogenic fungi [9]. Essential oils from lemongrass are widely used in flavours, fragrances, cosmetics, soaps, detergents and perfumery owing to their typical lemon and rose-like aroma.

The essential oils of *Cymbopogon* species mainly consist of the monoterpene fractions. The compounds identified in *Cymbopogon* *citratus* are mainly terpenes, alcohols, ketones, aldehyde and esters [10]. *Cymbopogon* essential oils have been known to possess impressive antibacterial, antifungal, antiyeast, insecticidal and insect repellent activities for a long time [11].

Cantaloupe melons are an excellent source of Vitamin A, Vitamin C, Potassium and Magnesium. It has been shown to possess useful medicinal properties such as analgesic, anti-inflammatory, anti-oxidant, anti-ulcer, anti-cancer, anti-microbial, diuretic, anti-diabetic, and anti-fertility activity Parle M *et al* [12]. Phytochemical analysis reveals that the seeds are a good source of flavonoids, phenolics, saponins, alkaloids and other secondary metabolites.

It has high iodine value and polyunsaturated fatty acids such as omega- 6 (linoleic acid), monounsaturated fatty acids such as omega-9 (oleic acid). It also consists of saturated fatty acids such as palmitic acid and stearic acid [13]. Consumer preference for this fruit is determined largely by its sweetness (i.e sugar content), flavor or aroma, texture and more recently as a rich source of phytonutrients [14].

Cucumis melo, in addition to its superior consumer preference, is an extremely healthful food choice as they are rich in ascorbic acid, carotene, folic acid, and potassium as well as a number of other human health-bioactive compounds [15]. Sugar content and composition are the major criteria used in judging the quality of the fruit of muskmelon [16]. Their seeds are an important source of bioactive compounds, which are considered to be health beneficial [17].

There were several researches reported about the combination of chitosan-lemongrass oil as edible coating of fruits. Edible coatings have a high potential to carry active ingredients such as anti-browning agents, colorants, flavours, nutrients, spices and antimicrobial compounds that can extend product shelf life and reduce the risk of pathogen growth on food surfaces [18].

Encapsulation with edible coatings is a promising technique that can solve the disadvantages of the use of bioactive compounds as food additives [19]. The effect of essential oil (AE) lemongrass (Cymbopogon citratus) at concentrations of 0.05, 0.1 and 0.25% by physico-chemical, mechanical and barrier properties on chitosan films was investigated. The results showed that films made with the essential oil of Cymbopogon citratus at concentrations of 0.1 and 0.25% Tween show a significant impact on the film thickness with respect to control and films with 0.05% AE. Chitosan films with essential oil and Tween 20 showed an increase in the solubility values from control. The addition of the essential oil on chitosan films reveals an effect on the values of tensile strength and elongation.

The addition of the essential oil of Cymbopogon citratus stable in the properties of water vapor permeability of films made based on Chitosan [20]. The effectiveness of combining lemongrass essential oil with chitosan as an edible coating for bell pepper was examined. Lemongrass essential oil at concentrations of 0.5% and 1.0% was incorporated into 0.5% and 1.0% chitosan solution and evaluated as a means of controlling anthracnose of bell pepper.

Fungal growth was effectively controlled by 0.5 % and 1.0 % essential oil. The application of 1.0% chitosan + 0.5% essential oil was significantly better at maintaining the fruit quality [21]. A study evaluated the effectiveness of edible coating using chitosan with lemongrass and thyme essential oils to improve the quality and extending the shelf life of strawberries during storage.

Strawberries (*Fragaria ananassa*) were coated by 1.0% chitosan with either (0.1 and 0.2 %) lemongrass oil or (0.1 and 0.2 %) thyme oil and uncoated fruit were used as control samples [22]. Chitosan and some natural plant extracts were tested to maintain post harvest quality of Navel orange.

The treatments included control (distilled water), chitosan at 2% and three aqueous plants extracts namely; olive water at 4%, rosemary at 4% and lemongrass at 3%.The fruits were stored for 12 weeks at 5±1°C and 90% RH. All treatments decreased weight loss, decay and delayed the changes in percentage of juice, total soluble solids, titratable acidity, carotene content and vitamin C compared with untreated fruits especially rosemary extract at 4% exhibited the best results in preserving fruit quality during the storage [23].

A study examined the effect of lemongrass oil *(Cymbopogon citratus),* citronella oil *(Cymbopogon winterianus)* and cajeput oil *(Melaleuca leucadendron)* against *Aspergillus niger* by the agar diffusion method. The selected oil was combined with the edible film (chitosan 1 % w/v or alginate 1 % w/v) and applied to preserve Cat Chu mango (infected by *A. niger* at 105 spores/ml) in 14 days at 30oC. The results also indicated that alginate (1 % w/v) combines with lemongrass oil (5 µl/ ml) maintained the antifungal effect after 14 days of preservation [24]. The aim of this work was to evaluate the combination of chitosan with lemongrass essential oil as edible coating to improve the quality and extend the shelf life of Cantaloupe (*Cucumis melo* L.) during storage.

Material and Method

Material

Cantaloupe (*Cucumis melo* L.) fruits were collected from Tien Giang province, Vietnam. Fruits were selected to ensure uniformity in size and peel colouration. Chitosan and lemongrass oil were purchased from Fluka® (USA). All other chemicals were of analytical grade.

Figure 1: Cantaloupe (*Cucumis melo* L.)

Researching Method

Effect of chitosan (% w/w): Lemongrass Essential Oil (% w/w) to Weight Loss (%) of Cantaloupe (Cucumis melo L.) Fruits under Different Storage Temperature

Cantaloupe (*Cucumis melo* L.) fruits were coated with different chitosan (% w/w): lemongrass essential oil (% w/w) (0.15%: 0.15%, 0.20%: 0.1%, 0.25%: 0.05%, respectively) to weight loss (%) of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature (4°C and 28°C). Weight loss (%) was determined by weighing regularly. All sampling were conducted at 4 days of interval for 16 days.

Effect of chitosan (% w/w): Lemongrass Essential Oil (% w/w) to Firmness (N) of Cantaloupe (Cucumis melo L.) Fruits under different Storage Temperature

Cantaloupe (*Cucumis melo* L.) fruits were coated with different chitosan (% w/w): lemongrass essential oil (% w/w) (0.15%: 0.15%, 0.20%: 0.1%, 0.25%: 0.05%, respectively) to firmness (N) of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature (4°C and 28°C). Firmness (N) was determined by texture analyzer. All sampling were conducted at 4 days of interval for 16 days.

Effect of chitosan (% w/w): Lemongrass Essential Oil (% w/w) to Total Soluble Solids (%) of Cantaloupe (Cucumis melo L.) Fruits under different Storage Temperature

Cantaloupe (*Cucumis melo* L.) fruits were coated with different chitosan (% w/w): lemongrass essential oil (% w/w) (0.15%: 0.15%, 0.20%: 0.1%, 0.25%: 0.05%, respectively) to total soluble solids ***(%)*** of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature (4°C and 28°C). Total soluble solids ***(%)*** were determined by refractometer. All sampling were conducted at 4 days of interval for 16 days.

Effect of chitosan (% w/w): Lemongrass Essential Oil (% w/w) to Total Acidity (%) of Cantaloupe (Cucumis melo L.) Fruits under different Storage Temperature

Cantaloupe (*Cucumis melo* L.) fruits were coated with different chitosan (% w/w): lemongrass essential oil (% w/w) (0.15%:

0.15%, 0.20%: 0.1%, 0.25%: 0.05%, respectively) to total acidity *(%)* of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature (4^{o}C and 28^{o}C). total acidity *(%)* were determined by using 10g aliquots of fruit puree in 50ml of distilled water and titrated with 0.1N Noah to an end-point of pH 8.1. All sampling were conducted at 4 days of interval for 16 days.

Effect of chitosan (% w/w): Lemongrass Essential Oil (% w/w) to Ascorbic Acid (mg/100g) of Cantaloupe (Cucumis melo L.) Fruits under different Storage Temperature

Cantaloupe (*Cucumis melo* L.) fruits were coated with different chitosan (% w/w): lemongrass essential oil (% w/w) (0.15%: 0.15%, 0.20%: 0.1%, 0.25%: 0.05%, respectively) to ascorbic acid ***(%)*** of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature (4^{o}C and 28^{o}C). Ascorbic acid ***(%)*** was determined by using titrimetric method with the titration of filtrate against 2, 6- dichlorophenol indophenol. All sampling were conducted at 4 days of interval for 16 days.

Effect of chitosan (% w/w): Lemongrass Essential Oil (% w/w) to carotenoid **(mg/100g) of Cantaloupe (Cucumis melo L.) Fruits under different Storage Temperature**

Cantaloupe (*Cucumis melo* L.) fruits were coated with different chitosan (% w/w): lemongrass essential oil (% w/w) (0.15%: 0.15%, 0.20%: 0.1%, 0.25%: 0.05%, respectively) to carotenoid (mg/100g) of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature (4^{o}C and 28^{o}C). Total carotenoid (mg/g) contents were determined by the modified method of Koala et al. (2013). All sampling were conducted at 4 days of interval for 16 days.

Effect of chitosan (% w/w): Lemongrass Essential Oil (% w/w) to Microbial Proliferation (Total Plate Count, cfu/g; Yeast, cfu/g; mold, cfu/g) of Cantaloupe (Cucumis melo L.) Fruits under different Storage Temperature

Cantaloupe (*Cucumis melo* L.) fruits were coated with different chitosan (% w/w): lemongrass essential oil (% w/w) (0.15%: 0.15%, 0.20%: 0.1%, 0.25%: 0.05%, respectively) to microbial proliferation (total plate count, cfu/g; yeast, cfu/g; mold, cfu/g) of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature (4^{o}C and 28^{o}C). Microbial proliferation (total plate count, cfu/g; yeast, cfu/g; mold, cfu/g) were determined by 3M-Petrifilm. All sampling were conducted at 4 days of interval for 16 days.

Effect of chitosan (% w/w): Lemongrass Essential Oil (% w/w) to Sensory Acceptability of Cantaloupe (Cucumis melo L.) fruits under different Storage Temperature

Cantaloupe (*Cucumis melo* L.) fruits were coated with different chitosan (% w/w): lemongrass essential oil (% w/w) (0.15%: 0.15%, 0.20%: 0.1%, 0.25%: 0.05%, respectively) to sensory acceptability of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature (4^{o}C and 28^{o}C). Sensory acceptability was based on 9-point Hedonic scale. All sampling were conducted at 4 days of interval for 16 days.

Statistical Analysis

The experiments were run in triplicate with three different lots of samples. Data were subjected to analysis of variance (ANOVA) and mean comparison was carried out using Duncan's multiple range test (DMRT). Statistical analysis was performed by the Statgraphics Centurion XVI.

Result & Discussion

Effect of chitosan (% w/w): Lemongrass Essential Oil (% w/w) to Weight Loss (%) of Cantaloupe (*Cucumis melo* L.) Fruits under different Storage Temperature

Fruit weight loss is mainly associated with respiration and moisture evaporation through the skin. The rate at which water is lost depends on the water pressure gradient between the fruit tissue and the surrounding atmosphere, and the storage temperature [25].

Dehydration will also cause increase in surface-wounded fruit. Edible coatings act as barriers, thereby restricting water transfer and protecting fruit skin from mechanical injuries, as well as sealing small wounds and thus delaying dehydration. Cantaloupe (*Cucumis melo* L.) fruits were coated with different chitosan (% w/w): lemongrass essential oil (% w/w) (0.15%: 0.15%, 0.20%: 0.1%, 0.25%: 0.05%, respectively) to weight loss (%) of Cantaloupe (*Cucumis melo* L.)

fruits under different storage temperature (4°C and 28°C). Weight loss (%) was determined by weighing regularly. All sampling were conducted at 4 days of interval for 16 days.

Table 1: Effect of chitosan (% w/w): lemongrass essential oil (% w/w) to weight loss (%) of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature

Temperature	4°C			28°C		
Chitosan: Lemongrass oil	0.15%: 0.15%	0.20%: 0.10%	0.25%: 0.05%	0.15%: 0.15%	0.20%: 0.10%	0.25%: 0.05%
0 day	0	0	0	0	0	0
4 days	0.74±0.03^a	0.25±0.02^b	0.21±0.00^b	0.93±0.01^a	0.31±0.02^b	0.33±0.03^b
8 days	1.16±0.01^a	1.03±0.03^b	0.97±0.01^b	1.32±0.02^a	1.12±0.01^b	1.15±0.02^b
12 days	1.95±0.02^a	1.14±0.02^b	1.12±0.03^b	2.11±0.00^a	1.28±0.03^b	1.30±0.01^b
16 days	2.41±0.03^a	1.89±0.00^b	1.85±0.02^b	2.64±0.03^a	2.04±0.00^b	2.09±0.02^b

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%)

Weight loss of fresh fruits during storage period may be due to loss in moisture content of the fruit and through respiration process during storage [26]. According to Ibrahim MA et al., [22], the weight loss of the samples at room temperature (24°C) after 3 days was 6.45, 5.50, 6.25 and 5.65% for the coated samples by chitosan+lemongrass oil 0.1, chitosan+lemongrass oil 0.2, chitosan+thyme oil 0.1 and chitosan+thyme oil 0.2%, respectively.

The decrease in moisture loss of coated fruits with chitosan+lemongrass oil and chitosan+thyme oil samples is obvious because of the higher water vapor barrier properties associated with the coatings [27] Ali et al [28].Reported that Chitosan treatment an effective control in weight loss reduction, maintained firmness, delayed changes in the peel colour and soluble solids concentration have been observed during 5 weeks of storage.

Similarly, in case of grapes, [29].Weight loss occurred mainly during the first 3 days of storage and was more pronounced for the control samples and those coated with a pure chitosan coating than for the samples with coatings containing bergamot oil which showed the smallest weight losses. Apart from strawberry and grape fruits, chitosan coatings have been effective at controlling water loss from other commodities, including cucumber and pepper [30], papaya [28] and longan fruit (Jiang and Li, 2001). Chitosan has been reported to be more effective at delaying weight loss in banana and mango [31] and strawberries [32] than are starch and cellulose derivatives. The slower rate of moisture loss from the chitosan coated fruits may be attributed to the additional barrier against diffusion through stomata [33]. According to Perez-Gago et al [34].Water loss can be reduced by covering with a plastic film or coating. In this study, the chitosan applied, formed a film on the fruit skin, reducing the water and weight loss

Effect of chitosan (% w/w): Lemongrass Essential Oil (% w/w) to Firmness (N) of Cantaloupe (Cucumis melo L.) Fruits under different Storage Temperature

Texture is a critical quality attribute in the consumer acceptability of fresh fruit and vegetables. Fruit texture properties are affected by cell turgidity and the structure and composition of the cell wall polysaccharides. Fruit firmness is a major attribute that dictates the postharvest life and quality of fruit. Chitosan coatings significantly reduced the loss in firmness of fruits during storage.

Fruit softening is due to deterioration in the cell structure, the cell wall composition and the intracellular materials. It is a biochemical process involving the hydrolysis of pectin and starch by enzymes, such as wall hydrolases. The initial softening of papaya is characterized by an increased solubility of the cell wall pectin and the softening of pectin [35]. Cantaloupe (*Cucumis melo* L.) fruits were coated with different chitosan (% w/w): lemongrass essential oil (% w/w)

(0.15%: 0.15%, 0.20%: 0.1%, 0.25%: 0.05%, respectively) to firmness (N) of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature (4°C and 28°C). Firmness (N) was determined by texture analyzer. All sampling were conducted at 4 days of interval for 16 days.

Table 2: Effect of chitosan (% w/w): lemongrass essential oil (% w/w) to firmness (N) of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature

Temperature	4°C			28°C		
Chitosan: Lemongrass oil	0.15%: 0.15%	0.20%: 0.10%	0.25%: 0.05%	0.15%: 0.15%	0.20%: 0.10%	0.25%: 0.05%
0 day	2.75±0.03a	2.75±0.03a	2.75±0.03a	2.75±0.03a	2.75±0.03a	2.75±0.03a
4 days	2.13±0.02b	2.69±0.00a	2.71±0.01a	2.03±0.01b	2.58±0.01a	2.60±0.02
8 days	2.04±0.02b	2.60±0.01a	2.62±0.00a	1.98±0.02b	2.42±0.02a	2.45±0.01a
12 days	1.86±0.01b	2.49±0.02a	2.53±0.03a	1.80±0.03b	2.37±0.03a	2.41±0.00a
16 days	1.71±0.03b	2.45±0.00a	2.50±0.02a	1.63±0.00b	2.29±0.02a	2.32±0.03a

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%)

According to Ibrahim MA et al [22].Coating of fruits showed a significant beneficial effect on firmness retention. Retention of firmness can be explained by retarded degradation of components responsible for the structural rigidity of the fruit, primarily the insoluble pectin and proto-pectin. During fruit ripening, depolymerization or shortening of pectin and other pectic substances occurs with an increase in pectinesterase and poly-galacutronase activities.

Low oxygen and high carbon-dioxide concentrations in the environment potentially reduce the activities of these enzymes and allow retention of the firmness of fruits and vegetables during storage [36]. The coating of fruits can be expected to modify the internal gas composition of fruits, especially reducing the oxygen concentrations and elevating carbon dioxide concentration which might explain the slower textural changes in the coated fruits [27]. Fruit firmness increased as chitosan concentration increased. The retention of firmness with chitosan coating is in agreement with the results of Bautista-Banos et al [3]. Where solo papayas treated with 1.5% chitosan coating were firmer than the control during 14 days storage, at ambient temperature. Fruits, such as mango, strawberry, tomato and pears, have also been reported to be firmer when coated with chitosan [37].

Effect of chitosan (% w/w): Lemongrass Essential Oil (% w/w) to Total Soluble Solids (%) of Cantaloupe (*Cucumis melo* L.) Fruits under different Storage Temperature

Fruits are rich in vitamins, minerals and supply arrays of colours, flavour, texture and bulkiness to the pleasure of eating. Cantaloupe (*Cucumis melo* L.) fruits were coated with different chitosan (% w/w): lemongrass essential oil (% w/w) (0.15%: 0.15%, 0.20%: 0.1%, 0.25%: 0.05%, respectively) to total soluble solids ***(%)*** of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature (4°C and 28°C). Total soluble solids ***(%)*** were determined by refractometer. All sampling were conducted at 4 days of interval for 16 days.

Table 3: Effect of chitosan (% w/w): lemongrass essential oil (% w/w) to total soluble solids (%) of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature

Temperature	4°C			28°C		
Chitosan: Lemongrass oil	0.15%: 0.15%	0.20%: 0.10%	0.25%: 0.05%	0.15%: 0.15%	0.20%: 0.10%	0.25%: 0.05%
0 day	18.65±0.01a	18.65±0.01a	18.65±0.01a	18.65±0.01a	18.65±0.01a	18.65±0.01a
4 days	17.89±0.03b	18.58±0.02a	18.60±0.00a	17.63±0.02b	18.50±0.02a	18.52±0.03a
8 days	17.68±0.02b	18.51±0.00a	18.56±0.02a	17.47±0.01	18.43±0.01a	18.45±0.03a
12 days	17.42±0.00b	18.48±0.01a	18.52±0.03a	17.31±0.04	18.37±0.02a	18.41±0.01a
16 days	17.30±0.01b	18.45±0.03a	18.47±0.02a	17.22±0.05	18.31±0.00a	18.35±0.03a

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%)

According to Ibrahim MA et al [22].The coated strawberry stored at high temperature recorded higher total soluble solid contents than those stored at low temperature in the first 3 days which ranged from 5.8 to 5.9 % for treatments stored at room temperature, while treatments stored at 4°C for 3 days recorded total soluble solids content from 5.6 to 5.8%. These results are in agreement with those reported by Vargas et al [38].

Total soluble solid, titrable acidity and ascorbic acid contents of peeled litchi fruit decreased markedly after 6 days of storage, compared to the peeled fruit before storage [39]. Hong et al [40].Reported the potential effects of chitosan coating and effects of different concentration of chitosan coatings on physiochemical characteristics of guava fruit during the cold storage.

Hong and his co-workers investigated that the soluble solids content of control and 0.5% chitosan coating fruit samples increased drastically however samples coated with 1.0 and 2.0% showed a slight increase during 12 days storage. Han et al [41]. Reported that the chitosan coating slowed down the changes in titratable acidity of strawberry and raspberry effectively delaying fruit ripening. The chitosan coating at 2.0% was probably able to modify the internal atmosphere of the fruit to prevent the decrease in titratable acidity contents. Therefore, the 2.0% chitosan coating produced a small change in titratable acidity throughout storage. Han et al [41].Also observed lower acidity loss during storage in strawberry, peach, tomato and litchi coated with chitosan.

Effect of chitosan (% w/w): Lemongrass Essential Oil (% w/w) to Total Acidity (%) of Cantaloupe (*Cucumis melo* L.) Fruits under different Storage temperature

Cantaloupe (*Cucumis melo* L.) fruits were coated with different chitosan (% w/w): lemongrass essential oil (% w/w) (0.15%: 0.15%, 0.20%: 0.1%, 0.25%: 0.05%, respectively) to total acidity *(%)* of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature (4°C and 28°C). total acidity *(%)* were determined by using 10g aliquots of fruit puree in 50ml of distilled water and titrated with 0.1N NaOH to an end-point of pH 8.1. All sampling were conducted at 4 days of interval for 16 days.

Table 4: Effect of chitosan (% w/w): lemongrass essential oil (% w/w) to total acidity (%) of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature

Temperature	**4°C**			**28°C**		
Chitosan: Lemongrass oil	0.15%: 0.15%	0.20%: 0.10%	0.25%: 0.05%	0.15%: 0.15%	0.20%: 0.10%	0.25%: 0.05%
0 day	1.19±0.02^{a}	1.19±0.02^{a}	1.19±0.02^{a}	1.19±0.02^{a}	1.19±0.02^{a}	1.19±0.02^{a}
4 days	1.12±0.00^{b}	1.15±0.01^{ab}	1.17±0.03^{a}	1.10±0.01^{b}	1.13±0.03^{ab}	1.15±0.01^{a}
8 days	1.10±0.01^{b}	1.13±0.02^{ab}	1.16±0.01^{a}	1.07±0.03^{b}	1.11±0.01^{ab}	1.14±0.00^{a}
12 days	1.05±0.02^{b}	1.10±0.01^{ab}	1.13±0.02^{a}	1.02±0.01^{b}	1.08±0.02^{ab}	1.11±0.01^{a}
16 days	1.01±0.03^{b}	1.08±0.02^{ab}	1.11±0.01^{a}	0.99±0.03^{b}	1.06±0.03^{ab}	1.08±0.02^{a}

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%)

Ibrahim MA et al. [22].Revealed that total acidity as % in coated strawberry fruits decreased with increasing the storage period. Results were in accordance with those of Atress et al [26].Who found that the total acidity significantly decreased as a function of storage time for coated strawberry due to the use of organic acid in the enzymatic reactions of respiration.

Effect of chitosan (% w/w): Lemongrass Essential Oil (% w/w) to Ascorbic Acid (mg/100g) of Cantaloupe (Cucumis melo L.) Fruits under different Storage Temperature

Cantaloupe (*Cucumis melo* L.) fruits were coated with different chitosan (% w/w): lemongrass essential oil (% w/w) (0.15%: 0.15%, 0.20%: 0.1%, 0.25%: 0.05%, respectively) to ascorbic acid (mg/ 100g) of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature (4°C and 28°C). Ascorbic acid ***(%)*** was determined by using titrimetric method with the titration of filtrate against 2, 6- dichlorophenol indophenol. All sampling were conducted at 4 days of interval for 16 days.

Table 3.5 Effect of chitosan (% w/w): lemongrass essential oil (% w/w) to ascorbic acid (mg/100g) of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature

Temperature	**4°C**			**28°C**		
Chitosan: Lemongrass oil	0.15%: 0.15%	0.20%: 0.10%	0.25%: 0.05%	0.15%: 0.15%	0.20%: 0.10%	0.25%: 0.05%
0 day	22.49±0.01^{a}	22.49±0.01^{a}	22.49±0.01^{a}	22.49±0.01^{a}	22.49±0.01^{a}	22.49±0.01^{a}
4 days	22.36±0.01^{b}	22.40±0.00^{ab}	22.43±0.03^{a}	22.31±0.02^{b}	22.38±0.00^{ab}	22.41±0.02^{a}
8 days	22.31±0.00^{b}	22.36±0.02^{ab}	22.39±0.02^{a}	22.26±0.01^{b}	22.34±0.02^{ab}	22.37±0.03^{a}
12 days	22.27±0.03^{b}	22.31±0.01^{ab}	22.34±0.00^{a}	22.21±0.03^{b}	22.28±0.03^{ab}	22.30±0.01^{a}
16 days	22.23±0.02^{b}	22.28±0.03^{ab}	22.31±0.01^{a}	22.18±0.00^{b}	22.24±0.01^{ab}	22.27±0.02^{a}

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%)

According to Ibrahim MA et al [22].The uncoated strawberry stored at 4°C for 3 days have a rapid decrease from 32.25 to 19.11 mg/100g. The ascorbic acid was progressively decreased to 8.24, 8.36, 8.47 and 7.97 mg/100g for the coated strawberry by chitosan+lemongrass oil 0.1, chitosan+lemongrass oil 0.2, chitosan+thyme oil 0.1 and chitosan+thyme oil 0.2%, at the end of 15 days of storage life, respectively. These results are in agreement with those obtained by Atress et al [26].Who stated that the ascorbic acid content of strawberries was decreased by extending the storage period.

The lowering of vitamin C loss of strawberries treated with edible coatings attributed to slowing down the respiration rate of fruits, as affected by coating which delays the deteriorative oxidation reaction of vitamin C. A recent study [42] indicated that coatings of chitosan and chitooligosaccharides applied to strawberries led to an improvement in fruit firmness and to a reduction in vitamin C and anthocyanin content.

Effect of chitosan (% w/w): Lemongrass Essential Oil (% w/w) to carotenoid (mg/100g) of Cantaloupe (*Cucumis melo* L.) Fruits under different Storage Temperature

Cantaloupe (*Cucumis melo* L.) fruits were coated with different chitosan (% w/w): lemongrass essential oil (% w/w) (0.15%: 0.15%, 0.20%: 0.1%, 0.25%: 0.05%, respectively) to carotenoid (mg/100g) of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature (4^{o}C and 28^{o}C).

Total carotenoid (mg/g) contents were determined by the modified method of Koala et al. (2013). All sampling were conducted at 4 days of interval for 16 days.

Table 6: Effect of chitosan (% w/w): lemongrass essential oil (% w/w) to carotenoid (mg/100g) of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature

Temperature	**4^{o}C**			**28^{o}C**		
Chitosan: Lemongrass oil	0.15%: 0.15%	0.20%: 0.10%	0.25%: 0.05%	0.15%: 0.15%	0.20%: 0.10%	0.25%: 0.05%
0 day	8.73±0.02^a	8.73±0.02^a	8.73±0.02^a	8.73±0.02^a	8.73±0.02^a	8.73±0.02^a
4 days	8.52±0.01^b	8.65±0.02^{ab}	8.69±0.01^a	8.47±0.00^b	8.56±0.01^{ab}	8.60±0.03^a
8 days	8.46±0.01^b	8.59±0.01^{ab}	8.63±0.03^a	8.42±0.01^b	8.51±0.03^{ab}	8.57±0.01^a
12 days	8.39±0.03^b	8.55±0.03^{ab}	8.58±0.02^a	8.33±0.03^b	8.45±0.00^{ab}	8.52±0.03^a
16 days	8.35±0.00^b	8.47±0.02^{ab}	8.52±0.01^a	8.29±0.02^b	8.37±0.01^{ab}	8.46±0.02^a

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (a = 5%)

Han et al [41]. Found that the coated strawberry fruits become redder and darker along the storage time. Garcia, et al [43].Stated that during storage, a significant decrease was observed in color of uncoated strawberries.

Effect of chitosan (% w/w): Lemongrass Essential Oil (% w/w) to Microbial Proliferation (Total Plate Count, cfu/g; Yeast, cfu/g; Mold, cfu/g) of Cantaloupe (*Cucumis melo* L.) Fruits under different Storage Temperature

The capacity of chitosan coating to inhibit the growth of several fungi has been shown for a wide variety of harvested commodities. The antibacterial activity and mechanism of action of acid-soluble chitosan has been explained based on membrane disruption, cell lysis, abnormal osmotic pressure, and additional chitosan coating around the bacteria based on integrity of cell membranes test, out membrane permeability assays and transmission electron microscopy observation.

In addition, biofilm biomass was markedly reduced after treating with acid-soluble chitosan, indicating the importance of biofilm formation in the antibacterial mechanism of chitosan.

Cantaloupe (*Cucumis melo* L.) fruits were coated with different chitosan (% w/w): lemongrass essential oil (% w/w) (0.15%: 0.15%, 0.20%: 0.1%, 0.25%: 0.05%, respectively) to microbial proliferation (total plate count, cfu/g; yeast, cfu/g; mold, cfu/g) of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature (4°C and 28°C). Microbial proliferation (total plate count, cfu/g; yeast, cfu/g; mold, cfu/g) were determined by 3M-Petrifilm. All sampling were conducted at 4 days of interval for 16 days.

Table 7: Effect of chitosan (% w/w): lemongrass essential oil (% w/w) to microbial proliferation (total plate count, cfu/g) of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature

Temperature	**4°C**			**28°C**		
Chitosan: Lemongrass oil	0.15%: 0.15%	0.20%: 0.10%	0.25%: 0.05%	0.15%: 0.15%	0.20%: 0.10%	0.25%: 0.05%
0 day	$6.3 \times 10^4 \pm 0.05^a$	$6.3 \times 10^4 \pm 0.05^a$	$6.3 \times 10^4 \pm 0.05^a$	$6.3 \times 10^4 \pm 0.05^a$	$6.3 \times 10^4 \pm 0.05^a$	$6.3 \times 10^4 \pm 0.05^a$
4 days	$5.4 \times 10^3 \pm 0.07^a$	$4.2 \times 10^3 \pm 0.06^{ab}$	$4.1 \times 10^3 \pm 0.08^b$	$5.4 \times 10^3 \pm 0.04^a$	$4.5 \times 10^3 \pm 0.07^{ab}$	$4.3 \times 10^3 \pm 0.08^b$
8 days	$4.6 \times 10^3 \pm 0.03^a$	$3.8 \times 10^3 \pm 0.02^{ab}$	$3.7 \times 10^3 \pm 0.04^b$	$4.9 \times 10^3 \pm 0.02^a$	$4.1 \times 10^3 \pm 0.03^{ab}$	$3.9 \times 10^3 \pm 0.04^b$
12 days	$7.6 \times 10^2 \pm 0.01^a$	$5.9 \times 10^2 \pm 0.03^{ab}$	$5.2 \times 10^2 \pm 0.04^b$	$8.1 \times 10^2 \pm 0.04^a$	$6.2 \times 10^2 \pm 0.05^{ab}$	$5.5 \times 10^2 \pm 0.04^b$
16 days	$5.3 \times 10^2 \pm 0.03^a$	$4.1 \times 10^2 \pm 0.02^{ab}$	$3.7 \times 10^2 \pm 0.03^b$	$5.7 \times 10^2 \pm 0.01^a$	$4.4 \times 10^2 \pm 0.04^{ab}$	$3.9 \times 10^2 \pm 0.03^b$

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%)

Table 8: Effect of chitosan (% w/w): lemongrass essential oil (% w/w) to microbial proliferation (yeast, cfu/g) of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature

Temperature	**4°C**			28°C		
Chitosan: Lemongrass oil	0.15%: 0.15%	0.20%: 0.10%	0.25%: 0.05%	0.15%: 0.15%	0.20%: 0.10%	0.25%: 0.05%
0 day	Nil	Nil	Nil	Nil	Nil	Nil
4 days	Nil	Nil	Nil	Nil	Nil	Nil
8 days	Nil	Nil	Nil	Nil	Nil	Nil
12 days	Nil	Nil	Nil	4^a	Nil	Nil
16 days	2^b	Nil	Nil	13^a	Nil	Nil

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%)

Table 9: Effect of chitosan (% w/w): lemongrass essential oil (% w/w) to microbial proliferation (mold, cfu/g) of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature

Temperature	**4°C**			**28°C**		
Chitosan: Lemongrass oil	0.15%: 0.15%	0.20%: 0.10%	0.25%: 0.05%	0.15%: 0.15%	0.20%: 0.10%	0.25%: 0.05%
0 day	Nil	Nil	Nil	Nil	Nil	Nil
4 days	Nil	Nil	Nil	Nil	Nil	Nil
8 days	Nil	Nil	Nil	Nil	Nil	Nil
12 days	Nil	Nil	Nil	Nil	Nil	Nil
16 days	Nil	Nil	Nil	3^a	Nil	Nil

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%)

According to the work carried out by El Ghaouth et al. (1992) on two postharvest pathogens, Botrytis cinerea and Rhizopus stolonifer, the antimicrobial activity of chitosan on strawberries appears to be related to the ability of this biopolymer to cause severe cellular damage to the mold and interfere in the secretion of polygalacturonases rather than its ability to induce plant defence enzymes.

Chitosan coatings containing bergamot oil produced the most effective antimicrobial activity, and showed the greatest inhibition of the respiration rates in terms of both O2 consumption and CO2 generation [29].

Chitosan is one of the best examples of edible coatings for improving the quality and resistivity of the fresh cut fruits [7, 44]. The effectiveness of chitosan in maintaining quality and extending shelf-life of sliced mango has been reported by Chien and his coworkers [44]. Assis and Han also proposed chitosan for extending the shelf-life of sliced apples and fresh strawberries, respectively [45, 41].

Chitosan-based edible film has been used on strawberries to increase the shelf-life [46]. A reduction in the counts of aerobic and coliforms microorganisms was also observed during storage.

According to Ibrahim MA et al [22].The bacterial counts gradually increased with the increasing of storage period at room and cooled temperature in all samples. Results were in accordance with those of Atress, et al [26].And Sharoba, et al [47].

The rate of respiration reduces in the chitosan treated fruits may be the reason of delayed senescence and a reduced susceptibility to decay [7]. Chitosan has a dual effect on hostpathogen interactions through its antifungal activity and its ability to induce plant defense responses. Moreover, as chitosan can form an edible film when applied to the surface of fruit and vegetables, it is clearly effective in conferring a physical barrier to moisture loss, delaying dehydration and fruit shriveling. Sanchez-Gonzalez et al [48].

Developed antibacterial composite films based on chitosan or hydroxypropylmethylcellulose and different essential oils (lemon, tea tree or bergamot), which were applied on the surface of inoculated agar plates, which were used as a model of a solid food system. The antibacterial activity of the chitosan films have enhanced when the added essential oils were more effective than the polymer, like in the case of Gram-positive bacteria.

Effect of chitosan (% w/w): Lemongrass Essential Oil (% w/w) to Sensory Acceptability of Cantaloupe (Cucumis melo L.) fruits under different Storage Temperature

One of the important factors in the perception of fruit quality is the colour. Cantaloupe (*Cucumis melo* L.) fruits were coated with different chitosan (% w/w): lemongrass essential oil (% w/w) (0.15%: 0.15%, 0.20%: 0.1%, 0.25%: 0.05%, respectively) to sensory acceptability of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature (4^{o}C and 28^{o}C). Sensory acceptability was based on 9-point Hedonic scale. All sampling were conducted at 4 days of interval for 16 days.

Table 10: Effect of chitosan (% w/w): lemongrass essential oil (% w/w) to sensory acceptability of Cantaloupe (*Cucumis melo* L.) fruits under different storage temperature

Temperature	4^{o}C			28^{o}C		
Chitosan: Lemongrass oil	0.15%: 0.15%	0.20%: 0.10%	0.25%: 0.05%	0.15%: 0.15%	0.20%: 0.10%	0.25%: 0.05%
0 day	8.65±0.02^{a}	8.65±0.02^{a}	8.65±0.02^{a}	8.65±0.02^{a}	8.65±0.02^{a}	8.65±0.02^{a}
4 days	8.47±0.01^{b}	8.53±0.01^{ab}	8.59±0.03^{a}	8.29±0.03^{b}	8.44±0.01^{ab}	8.53±0.01^{a}
8 days	8.42±0.00^{b}	8.47±0.03^{ab}	8.52±0.01^{a}	8.17±0.02^{b}	8.32±0.00^{ab}	8.47±0.03^{a}
12 days	8.37±0.03^{b}	8.42±0.02^{ab}	8.46±0.02^{a}	8.06±0.00^{b}	8.26±0.01^{ab}	8.41±0.02^{a}
16 days	8.24±0.00^{b}	8.36±0.03^{ab}	8.40±0.00^{a}	8.00±0.01^{b}	8.14±0.04^{ab}	8.33±0.01^{a}

Note: the values were expressed as the mean of three repetitions; the same characters (denoted above), the difference between them was not significant (α = 5%)

Kittur et al [31].Observed that 1.0% chitosan coated mangoes had better sensory traits than the control and the waxol treated mangoes, after 21 days of storage. According to Ibrahim MA et al [22].The coated strawberries had a visual microbial spoilage observed on the 5th day for samples stored at room temperature, while samples stored under cooling had a visual microbial spoilage on the 16th day, and the sensory analysis was also interrupted.

Results were in accordance with those of Garcia et al [43]. And Perdones et al [48]. Chitosan coating delayed the decline in sensory quality, and extended shelf life of litchi [5]. Pen and Jiang (2003) reported that chitosan coating improved the quality attributes and extended shelf life of fresh-cut Chinese water chestnut by reducing respiration and inhibiting activities of polyphenol oxidase and peroxidase. Chitosan coating can be used as a vehicle for incorporating functional ingredients, such as antimicrobials or nutraceutical compounds that could enhance the effects of chitosan coating or reinforce the nutritional value of the strawberries [38, 49, 48]. Fruit darkens, skin colour becomes less chromatic and surface browning develops. Less red skin and darkening due to oxidative browning reactions have been found to be more marked in ripe strawberries that suffer greater moisture loss during storage [50, 51].

Conclusion

Cantaloupe *(Cucumis melo* L.) is one of the economically important fruit in the world and the important quality determining parameters of it are carbohydrates and antioxidants. The use of edible coatings signifies one of the significant methods for preserving quality. The essential oil of *Cymbopogon citratus* are mainly terpenes, alcohols, ketones, aldehyde and esters. The use of edible coatings in combination with antimicrobial properties or with amalgamation of antimicrobial compounds is a potential alternative to enhance the safety and quality of fresh fruits.

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