





Evaluating the Impact of Edible Coating on the Shelf Life of Carrot (*Daucus carota*) and Green Pepper (*Capsicum annuum*)

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Abstract	Article History
<p>Edible coatings have emerged as a promising method to extend the shelf-life of fresh produce, including carrots and green peppers. This study investigates the impacted influence of coating of the carrots and peppers stored for 12 days. Standard microbial analysis was done using standard methods. The Total heterotrophic bacteria count (THBC) in coated carrots and peppers ranged from 8.8×10^4 CFU/g to 1.51×10^6 CFU/g while the THBC in pepper ranged from 4.4×10^4 CFU/g to 9.4×10^5 CFU/g. The THBC in uncoated carrot ranged from 8.8×10^4 CFU/g to 2.8×10^6 CFU/g while the THBC in uncoated pepper ranged 9.4×10^5 CFU/g to 1.9×10^6 CFU/g. The Staphylococcus count in coated carrots ranged 6.9×10^3 CFU/g to 9.4×10^6 cfu/g while the Staphylococcus count in pepper ranged from 4×10^3 CFU/g to 8.8×10^3 CFU/g. The Staphylococcus count in Uncoated carrot and pepper ranged from 9.4×10^3 CFU/g to 3.8×10^4 CFU/g and 8.8×10^3 CFU/g to 1.02×10^4 CFU/g respectively. The fungi count in Uncoated carrot ranged 3×10^3 CFU/g to 2.2×10^4 CFU/g while the fungi count in pepper ranged from 2.2×10^3 CFU/g to 1.9×10^4 CFU/g. The fungi count in coated carrots ranged from 1.2×10^3 CFU/g to 3×10^3 CFU/g while the fungi count in pepper ranged from 1.4×10^3 to 2.2×10^3 CFU/g. The Coliform count in coated carrots ranged from 2.2×10^3 to 1.02×10^4 CFU/g to while the Coliform count in pepper ranged from 3.0×10^3 CFU/g to 1.29×10^4 CFU/g. The Coliform count in Uncoated carrot ranged from 7.6×10^3 CFU/g to 1.12×10^4 CFU/g while the Coliform pepper ranged from 5.9×10^3 CFU/g to 1.42×10^4 CFU/g. Dominant bacteria included <i>Staphylococcus aureus</i> (24.6%), <i>Bacillus subtilis</i> (24.6%), and <i>Escherichia coli</i> (14.7%), while fungi were predominantly <i>Aspergillus niger</i> (31%) and <i>Aspergillus flavus</i> (27.6%). Proximate analysis revealed uncoated carrots had 5.40% ash, 30.40% moisture, and 42.62% carbohydrates initially, with changes observed by day 15. Similarly, uncoated peppers had 80.32% moisture, 5.90% protein, and 5.50% carbohydrates on day 0. Coated samples showed minimal changes in nutritional composition over time. The study concludes that honey wax coating significantly reduces microbial load, extends shelf life, and maintains the nutritional quality of carrots and peppers, recommending its application for preserving vegetables.</p>	<p>Received: 03 May 2025 Accepted: 11 May 2025 Published: 17 May 2025</p> <p>Scan QR code to view*</p>  <p>License: CC BY 4.0*</p>  <p>Open Access article.</p>
<p>Keywords: Edible coating, Green peeper, Carrot, Microbial quality, Proximate and Vitamin composition</p> <p>How to cite this paper: Omorodion, N. J., & Osuala, P. U. (2025). Evaluating the Impact of Edible Coating on the Shelf Life of Carrot (<i>Daucus carota</i>) and Green Pepper (<i>Capsicum annuum</i>). <i>IPS Journal of Applied Microbiology and Biotechnology</i>, 4(1), 132–143. https://doi.org/10.54117/ijamb.v4i1.54</p>	

Introduction

The waxy layer that naturally covers the surface of all fruits and vegetables helps them retain water. Fruit respiration is accelerated and the protective effect of the waxy covering is compromised when fruits or abrasions are wiped with wrapping paper. Therefore, another continuous or discontinuous film is applied to fruits and vegetables to provide a protective layer. Fruit and vegetable skins have also inspired the use of edible coatings (Goldstein et al., 1992). These are a thin covering of edible components that prevent food soluble materials like oxygen and water from evaporating (Bourtoom, 2008; Kotiyal and Singh, 2023). According to McHugh and Krochta (1994), the coating is an essential component of the food that can be consumed as a whole.

According to Valero et al. (2013), a "edible coating" is a thin covering of digestible material that protects food from oxygen, external microorganisms, moisture, and solute movement. By lowering respiration, gas exchange, oxidative reaction rates, moisture, and solute migration, among other physiological problems, edible coatings with a semi-permeable barrier seek to increase shelf life (Dhall, 2013; Shi et al., 2024).

Creating a barrier between respiration and transpiration is the primary purpose of an edible covering. As an antimicrobial and antioxidant, it extends the shelf life and quality of both fresh and processed fruits and vegetables. Coatings can enhance the appearance of green peppers and carrots and prolong their consumer attractiveness because they are staple foods that are susceptible to microbial spoilage, which

shortens their shelf life and causes financial losses (Giannakourou & Tsironi, 2021).

Fruits and vegetables experience the most postharvest loss because of their perishable nature. Chopped fruits and vegetables are growing in popularity as consumers choose fresh and organic items and as lifestyle changes are proven to be successful. It is still challenging for the food business to continue producing cutting-edge food items for an extended period of time.

A balanced diet must include both fruits and vegetables (Riva et al., 2020). Biochemical changes such as ethylene production, softening, pigmentation change, respiration rate, acidity, and weight loss are necessary to reduce post-harvest losses.

One tactic to satisfy the present need is the use of edible films and coatings (Tavassoli-Kafrani et al., 2016). Edible coatings preserve the quality of fruits and vegetables, which makes them valuable for postharvest management strategies. Physical alterations during preservation can be prevented by applying an edible layer of proteins, polysaccharides, and lipids. The main function of an edible coating is to create a barrier between respiration and transpiration. Edible coatings act as various functional compounds, including antioxidant and antibacterial substances, enhancing the quality and extending the shelf life of fresh and minimally processed produce. These coatings form a protective layer around fruits and vegetables, effectively covering the stomata. This action reduces the rate of transpiration, subsequently decreasing weight loss (Prasad et al., 2018). Their effectiveness has been shown in numerous fruits and vegetables, such as radish, potato, tomato, turnip, guava, plum, mango, apricot, banana, orange, and several others. Natural biomolecules known as edible coatings are utilized to enhance the appearance and preservation of fruits and vegetables (Kotiyal et al., 2024).

The safety and nutritional value of the fruits and vegetables are improved by adding additional active substances to edible films and coatings. To modify the structure and advance the characteristics of coatings, food grade extracts such as flavoring agents, pigments, antioxidants, and antimicrobials can be added. This improves the quality of produce when applied to it (Nawab et al., 2017). Due to their edibility, non-toxic makeup and cost-effectiveness in comparison to alternative synthetic coatings, edible coatings are in great demand from consumers today. The creation of edible biodegradable coatings and films as alternatives to synthetic polymers, which cause less environmental harm than plastic waste, has increased.

A lot of research is currently being done on edible coating and the materials used in the edible coating in food processing technology to decrease waste and limit loss and is healthy, functional for storage and market distribution. The shelf-life of fresh produce like carrots and green peppers is often limited by rapid spoilage, primarily due to water loss, microbial growth, and enzymatic degradation. This rapid deterioration leads to significant food waste and financial losses in supply chains and households, posing a challenge for maintaining food security and sustainability. Edible coatings, which create

a semi-permeable barrier on the surface of fruits and vegetables, have been proposed as a potential solution to extend freshness by reducing moisture loss, slowing respiration rates, and inhibiting microbial activity. However, while edible coatings have been explored for various fruits, their specific impact on the shelf-life and quality of vegetables, particularly carrots and green peppers, remains under-researched. This study aims to evaluate how edible coating affect the shelf-life and quality of carrot and green pepper, providing insights into practical applications that can reduce post-harvest losses and support food supply stability. Therefore, the aim of the study is to ascertain the impact of edible coating on the shelf life of two widely consumed commodities carrot and green pepper.

Materials and Methods

Samples Collection

A total of 24 samples of fresh carrots and green peppers of different sizes, varieties and the same maturity levels each was purchased from Choba Markrt in Port Harcourt, Rivers State. Using a sterile polythene bag properly labelled for each sample. For comparison, a set of fresh carrots and green peppers was treated with distilled water

Preparation and Application of Edible Coating

Edible coating was prepared using natural polymer such as beeswax. The prepared edible coatings were applied evenly on the carrots and green peppers using dipping methods (Guilbert et al., 1996).

Storage Conditions

The coated and uncoated samples were stored under controlled conditions to simulate real-world. The samples were placed on a sterile tray for 12 days at ambient temperature and labelled as CC -For coated carrot sample, CP -For coated pepper sample, UCC -For uncoated carrot sample, UCP -For uncoated pepper sample.

Microbial Analysis

Ten gram (10g) each of coated and uncoated carrots / green peppers were weighed into 90ml peptone solution for about 3 mins under sterile conditions and microbiological analysis was carried out on day 0,3,6,9, and day 12. Ten (10) fold serial dilution of the two samples (carrot and green pepper). A plastic rack was arranged with ten (10) sterile test tubes containing 9ml of sterile 0.1 peptone water. Ten gram (10g) of each sample was weighed using electronic weigh balance. The weighed samples were carefully introduced into each of the conical flask containing 90ml peptone solution using a sterile spatula, vigorously mixed and labeled as dilution 10^{-1} . A sterile pipette was used to transfer 0.1 ml solution from dilution 10^{-1} to the next test tube (dilution 10^{-2}). Subsequent stepwise transfers were carried out using a sterile pipette for each transfer until dilution 10^{-4} is reached. The content of each test tube was shaken vigorously before transferring an aliquot (0.1 ml) of the mixture into the next test tube.

Enumeration of Microorganisms

Total Heterotrophic Bacteria Count (THBC): From the diluted samples, 0.1ml aliquots were plated on Plate count agar (PCA). The spread method was employed, and inoculation was

performed aseptically using sterile hockey sticks. Plates were labelled according to their dilutions. Total heterotrophic bacteria count (THBC) of the coated and uncoated carrots as determined by culturing the diluted samples on plates count agar plates using pour plate method. The culture plates was incubated for 24 hours at 37 °C. After incubation the colonies was manually counted and described according to their morphological characteristics and results was recorded in CFU/g.

Total Coliform Count (TCC): From the diluted samples, 0.1ml aliquots was plated on MacConkey agar (MAC). The spread method was employed, and inoculation was performed aseptically using sterile hockey sticks. Plates were labelled according to their dilutions. Total coliform count (TCC) of the coated and uncoated carrots was determined by culturing the samples on MacConkey agar plates using pour plate method. The culture plates was incubated for 24 hours at 37^o C. After incubation the colonies was manually counted and described according to their morphological characteristics and results was recorded in CFU/g.

Total Staph Count (TSC): From the diluted samples, 0.1ml aliquots was plated on Mannitol salt agar (MSA). The spread method was employed, and inoculation was performed aseptically using sterile hockey sticks. Plates were labelled according to their dilutions. Total Staphylococcal count (TSC) of the coated and uncoated carrots was determined by culturing the samples on Mannitol Salt agar plates using pour plate method. The culture plates was incubated for 24 hours at 37^o C. After incubation the colonies was manually counted and described according to their morphological characteristics and results was recorded in CFU/g.

Total Fungi Count (TFC): From the diluted samples, 0.1ml aliquots was plated on Potato dextrose agar (PDA). The spread method was employed, and inoculation was performed aseptically using sterile hockey sticks. Plates were labelled according to their dilutions. Total Fungi count (TFC) of the coated and uncoated carrots was determined by culturing the samples on plates dextrose agar plates using pour plate method. The culture plates was incubated for 3- 5 days at 37^o C. After incubation, the colonies will be manually counted. After incubation the colonies was manually counted and described according to their morphological characteristics and results was recorded in CFU/g.

The number of bacteria colonies was determined for each plates. The total heterotrophic bacterial count was obtained from plate count agar culture after 24 hours of incubation, the total coliform count was obtained from MacConkey agar culture after 24 hours of incubation, and the total staphylococcus spp count was obtained from mannitol salt agar culture after 24 hours of incubation. The colony counts were expressed as colony forming units per gram (CFU/g). Individual bacteria colonies were selected from the previously incubated media based on their morphological features such as colony size, color, texture, elevation and odor. These were then sub-cultured and streaked on freshly prepared nutrient agar plates using the streak plate method and incubated at 37 °C for 24 hours to obtain pure colonies. Various biochemical tests

was conducted for further identification and confirmation of the pure bacterial isolates which include:

Isolation and identification fungi isolates

Fungi colonies will be isolated and streaked on freshly prepared PDA plates incubated for 3-5days at 37 °C. After 3-5 days pure colonies will be stored in freshly prepared PDA slants for further microscopic identification. The colour, shape, edge, size and texture of the fungi isolates will be microscopically identified and results will be recorded.

A sterile inoculating needle were used to pick discrete colonies on the fungal plates and streaked on freshly prepared PDA plates. The inoculated plates were incubated at room temperature 37°C for 3-5 days to obtain pure isolates. The fungal isolates from coated carrots and green peppers was identified microscopically by the observation of their mycelia under the microscope at ×40 objectives with lactophenol cotton blue stain and results would be recorded.

Physiochemical Analysis

The proximate composition of the samples was analyzed for moisture, ash, protein, fat and fibre by the method of AOAC (2005). The carbohydrate content was calculated by subtraction method Pomeranz (1971), Jabeen et al. (2019). Standard method of AOAC (2012) was used to determine Vitamins.

Statistical analyses

Analysis of variance (ANOVA) was used to compare means at $p < 0.05$. This analyses was performed to visualize the association between the microbial loads of the coated and uncoated samples using SPSS (Statistical Package for the Social Sciences), also known as IBM SPSS Statistics, is a software package used for the analysis of statistical data.

Results

Total heterotrophic Bacteria Count of Coated and Uncoated Carrots and Pepper Studied

The total heterotrophic bacteria count of the coated and uncoated carrot and pepper showed varying counts. On day 0, uncoated carrot had a count of 8.8×10^4 CFU/g while the uncoated pepper sample had a THBC of 9.4×10^5 CFU/g. On day 3, the coated carrot had counts of 9.6×10^4 CFU/g while coated pepper had a 4.4×10^4 CFU/g count; the uncoated carrot had a count of 2.8×10^5 CFU/g while the uncoated pepper had a count of 1.0×10^5 CFU/g. The final day of analysis (Day 15) was not analyzed due to excessive deterioration (spoilage) but day 12 showed higher counts as the coated carrot had a 1.16×10^5 CFU/g count while the coated pepper had a count of 3.0×10^5 CFU/g. The uncoated carrot had 6.5×10^6 CFU/g while the uncoated pepper had a count of 3.1×10^6 CFU/g. Details of counts obtained on days 6 and 9 are as presented in Figures 1 below

Staphylococcus Counts of Coated and Uncoated Carrots and Pepper Studied

The staphylococcus count of the coated and uncoated carrot and pepper showed varying counts. On day 0, uncoated carrot had a count of 9.4×10^4 CFU/g while the uncoated pepper sample had a staphylococcus count of 8.8×10^3 CFU/g. On day

3, the coated carrot had counts of 7.2×10^3 CFU/g while coated pepper had a 6.9×10^3 CFU/g count. The uncoated carrot had a count of 9.4×10^3 CFU/g while the uncoated pepper had a count of 8.8×10^3 CFU/g. The final day of analysis (Day 15) was not analyzed due to excessive deterioration (spoilage) but day 12

showed higher counts as the coated carrot had a 6.9×10^3 CFU/g count while the coated pepper had a count of 4.0×10^3 CFU/g. The uncoated carrot had 2.5×10^4 CFU/g while the uncoated pepper had a count of 2.0×10^4 CFU/g. Details of counts obtained on days 6 and 9 are as presented in Figures 2 below.

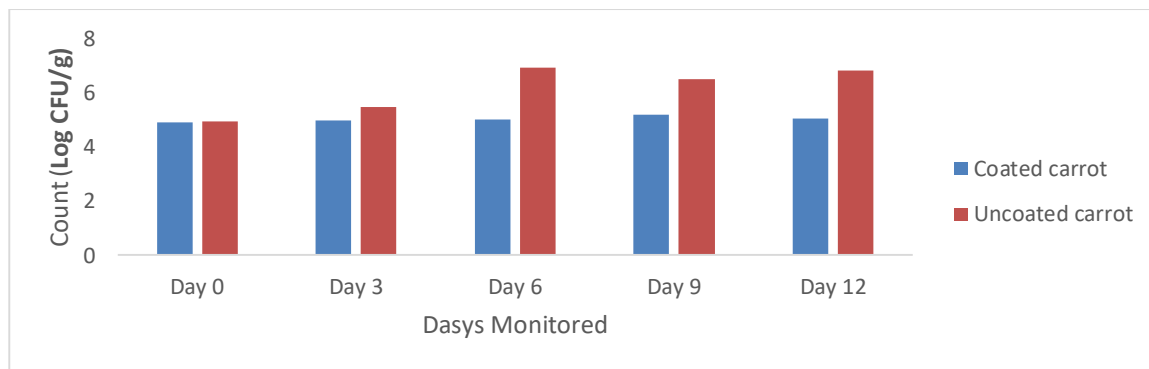


Figure 1: Bar chart of total heterotrophic Bacteria Count of Coated and Uncoated Carrots



Figure 2: Bar chart of total heterotrophic Bacteria Count of Coated and Uncoated Pepper



Figure 3: Bar chart of Staphylococcus Counts of Coated and Uncoated Carrots Studied

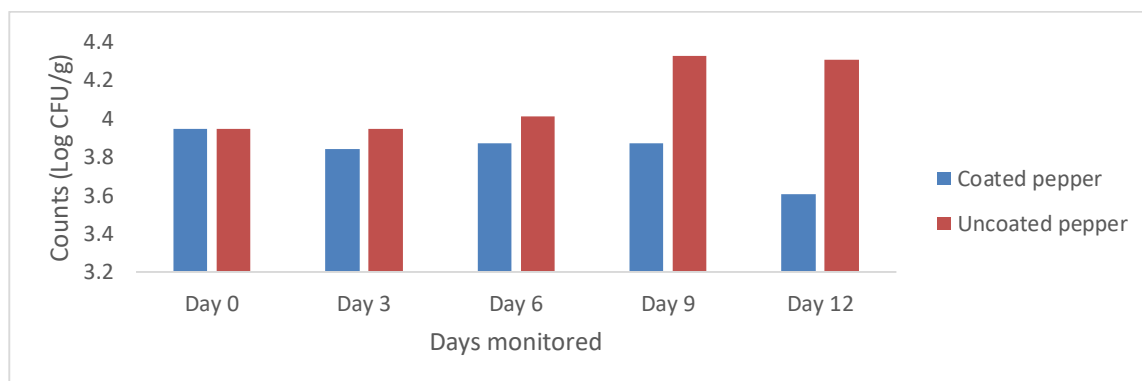


Figure 4: Bar chart of Staphylococcus Counts of Coated and Uncoated Pepper Studies.

Total Coliform Counts of Coated and Uncoated Carrots and Pepper Studied

The total coliform count of the coated and uncoated carrot and pepper showed varying counts. On day 0, uncoated carrot had a count of 1.02×10^4 CFU/g while the uncoated pepper sample had a coliform count of 1.29×10^4 CFU/g. On day 3, the coated carrot had counts of 5.6×10^3 CFU/g while coated pepper had a 4.7×10^3 CFU/g count. The uncoated carrot had a count of 1.12×10^4 CFU/g while the uncoated pepper had a count of 1.42×10^4 CFU/g. The final day of analysis (Day 15) was not analyzed due to excessive deterioration (spoilage) but day 12 showed higher counts as the coated carrot had a 2.2×10^3 CFU/g count while the coated pepper had a count of 3.1×10^3 CFU/g. The uncoated carrot had 7.6×10^3 CFU/g while the uncoated pepper had a count of 5.9×10^3 CFU/g. Details of counts obtained on days 6 and 9 are as presented in Figures 5 below.

Fungi Counts of Coated and Uncoated Carrots and Pepper Studied

The total fungi count of the coated and uncoated carrot and pepper showed varying counts. On day 0, uncoated carrot had a count of 3.0×10^3 CFU/g while the uncoated pepper sample had a fungi count of 2.2×10^3 CFU/g. On day 3, the coated carrot had counts of 1.6×10^3 CFU/g while coated pepper had a 1.4×10^3 CFU/g count. The uncoated carrot had a count of 3.4×10^3 CFU/g while the uncoated pepper had a count of 3.9×10^3 CFU/g. The final day of analysis (Day 15) was not analyzed due to excessive deterioration (spoilage) but day 12 showed higher counts as the coated carrot had a 1.2×10^3 CFU/g count while the coated pepper had a count of 1.8×10^3 CFU/g. The uncoated carrot had 2.2×10^4 CFU/g while the uncoated pepper had a count of 1.9×10^4 CFU/g. Details of counts obtained on days 6 and 9 are as presented in Figures 6 below.



Figure 5: Bar chart of Total Coliform Counts of Coated and Uncoated Carrot Studied

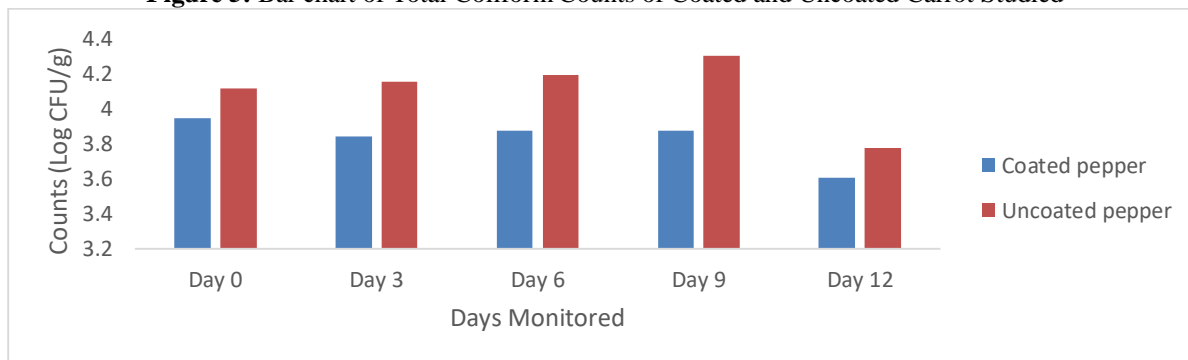


Figure 6: Bar chart of Total Coliform Counts of Coated and Uncoated Pepper Studied

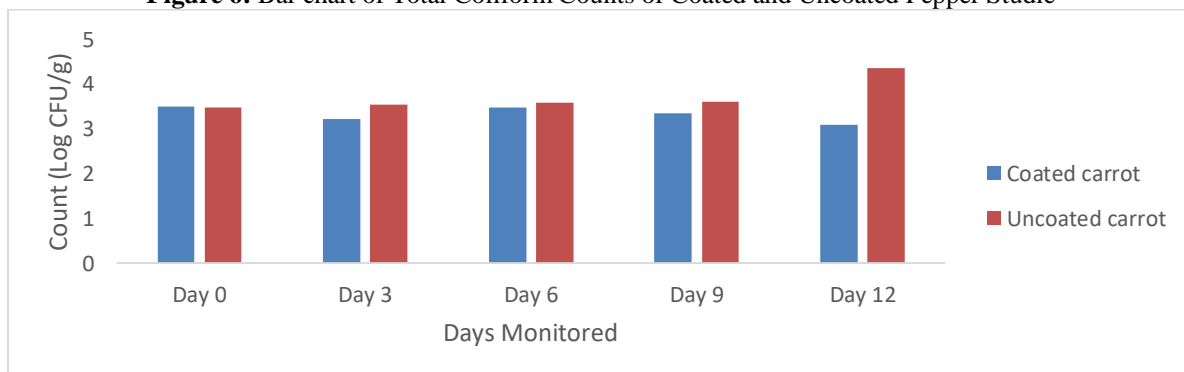


Figure 7: Bar chart of Fungi Counts of Coated and Uncoated Carrot Studied



Figure 8: Bar chart of Fungi Counts of Coated and Uncoated Pepper Studied

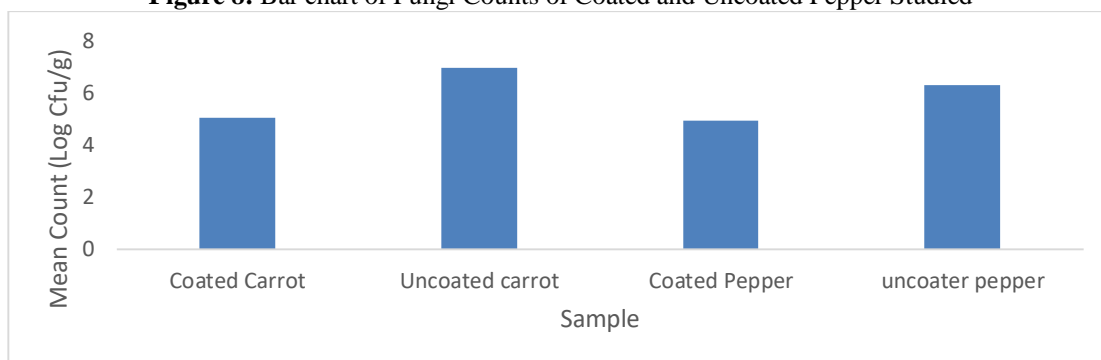


Figure 9: Bar Chart of the Mean Total Heterotrophic Bacteria Count of Coated and Uncoated Green Pepper and Carrot

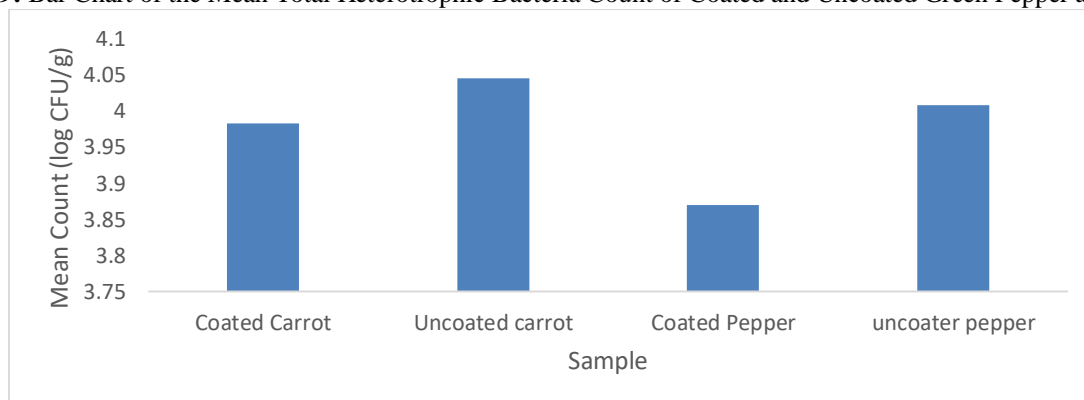


Figure 10: Bar Chart of the Mean Total Staphylococcus Count of Coated and Uncoated Green Pepper and Carrot

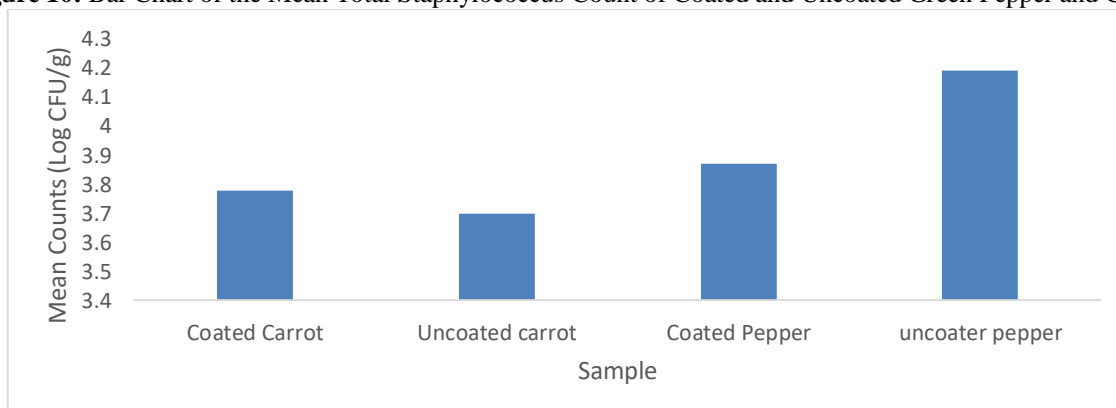


Figure 11: Bar Chart of the Mean Total Coliform Count of Coated and Uncoated Green Pepper and Carrot

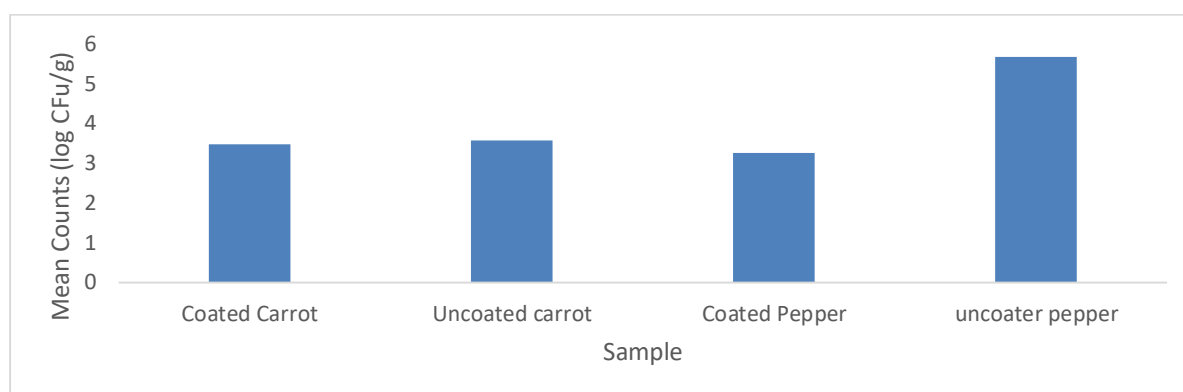


Figure 12: Bar Chart of the Mean Total Fungi Count of Coated and Uncoated Green Pepper and Carrot

Table 1: Frequency of Occurrence of Bacteria Isolated from Coated and Uncoated Carrots and Pepper Studied

Bacteria genera	Carrot		Pepper		Total N (%)
	Coated n (%)	Uncoated n (%)	Coated n (%)	Uncoated n (%)	
<i>Escherichia coli</i>	0(0.0)	5(29.4)	0(0.0)	4(19.0)	9(14.7)
<i>Staphylococcus spp.</i>	5(35.7)	4(23.5)	3(33.3)	3(14.3)	15(24.6)
<i>Bacillus spp.</i>	4(28.5)	1(5.9)	3(33.3)	7(33.3)	15(24.6)
<i>Micrococcus spp.</i>	5(35.7)	4(23.5)	3(33.3)	2(9.5)	14(22.9)
<i>Serratia masecens</i>	0(0.0)	3(17.6)	0(0.0)	0(0.0)	3(4.9)
<i>Enterobacter spp.</i>	0(0.0)	0(0.0)	0(0.0)	5(23.8)	5(8.2)
Total	14(22.9)	17(27.9)	9(14.7)	21(34.4)	61(100.0)

Table 2: Frequency of Occurrence of Fungi Isolated from Coated and Uncoated Carrots and Pepper Studied

Bacteria genera	Carrot		Pepper		Total N (%)
	Coated n (%)	Uncoated n (%)	Coated n (%)	Uncoated n (%)	
<i>Aspergillus niger</i>	4(100.0)	3(23.1)	2(50.0)	0(0.0)	9(31.0)
<i>Aspergillus flavus</i>	0(0.0)	4(30.7)	1(25.0)	3(37.5)	8(27.6)
<i>Mucor spp</i>	0(0.0)	2(15.4)	1(25.0)	1(12.5)	4(13.8)
<i>Alternaria spp.</i>	0(0.0)	2(15.4)	0(0.0)	2(25.0)	4(13.8)
<i>Saccharomyces cerevisiae</i>	0(0.0)	2(15.4)	0(0.0)	2(25.0)	4(13.8)
Total	4(13.8)	13(44.8)	4(13.8)	8(27.9)	29(100.0)

Proximate composition of Coated and Uncoated Carrots and Pepper Studied

The proximate composition of coated and uncoated carrot and pepper samples studied showed that one Day 0, Ash content of the respective samples (Uncoated carrot and pepper) studied were 5.40 and 5.0%; Moisture content were 30.40% and 80.32%; Lipid content were 0.53 and 0.64%; Crude protein 3.96% and 5.90%, Crude fibre were 16.40% and 5.50% and Carbohydrate 42.62% and 5.50% respectively. All samples showed varying figure from day 0 figures on day 15. The

values for uncoated carrot for Ash, Moisture content, Lipid, crude protein, crude fibre and carbohydrates were: 5.5%, 26.2%, 0.63%, 5.90%, 16.14% and 44.8% while that of Uncoated pepper were 7.50%, 50.32%, 0.64%, 0.40%, 11.2%, and 33.75%. The values of coated carrots for Ash, Moisture content, Lipid, crude protein, crude fibre and carbohydrates were: 5.40%, 26.60%, 0.64%, 5.90%, 16.14% and 44.8% while that of the coated pepper samples were 7.50%, 51.11%, 0.61%, 0.40%, 11.2% and 33.85%. (See Table 3).

Table 3: Proximate composition of Coated and Uncoated Carrot and Pepper Studied on days 1 and 9.

Sample Code	Ash (%)	Moisture Content (%)	Lipid (%)	Crude Protein (%)	Crude Fibre (%)	Carbohydrate (%)
Day 0						
Uncoated Carrot	5.40	30.40	0.53	3.96	16.40	42.62
Uncoated Pepper	5.0	80.32	0.64	5.90	3.0	5.50
Day 9						
Uncoated Carrot	5.5	26.2	0.63	5.90	16.14	44.8
Coated Carrot	5.40	26.60	0.64	5.90	16.14	44.8
Uncoated Pepper	7.50	50.32	0.64	0.40	11.2	33.75
Coated Pepper	7.50	51.11	0.61	0.40	11.2	33.85

Table 4: Vitamin composition of coated and uncoated carrot and green pepper

Sample	Vitamin A (ug)	Vitamin B (ug)
Coated carrot	846.19	0.36
Uncoated carrot	1758.42	0.82
Coated pepper	113.96	14.31
Uncoated pepper	178.45	23.76

Discussion

Microbial quality of coated and uncoated carrot and green pepper

The impact of honey wax coating on the shelf life of green peppers and carrots was examined in this study. Honey wax, an edible coating, is used to enhance the appearance of food and ensure its safety due to its environmentally beneficial properties. During handling, processing, and storage, they serve as a barrier to keep out gasses and moisture. Through their action or the addition of an antimicrobial chemical, it improves food safety and lessens food deterioration. The study evaluated honey wax's efficacy as a natural antimicrobial coating in prolonging shelf life by comparing the bacteria counts in coated and untreated samples. The antibacterial effectiveness of honey wax in prolonging shelf life was evaluated by measuring the microbiological quality of coated and untreated samples during a 12-day period. Prior research has emphasized the advantages of coatings made of honey and wax, pointing to their antibacterial qualities and capacity to form a barrier that inhibits moisture loss and respiration, maintaining freshness. Yaman and Bayoindiri (2002) discuss how cherries are affected by edible covering. According to their research, this coating may help cherries lose weight while also improving their firmness, ascorbic acid concentration, titratable acidity, and skin color. Additionally, it extended the cherries' shelf life. According to Lee et al. (2003) and Bai et al. (2003), who investigated the effect of edible coating on apple slices and varieties, these coatings also demonstrated their ability to lengthen the shelf life of apples. Microbial

counts obtained from this fresh produce both coated and uncoated are as follows

The Total Heterotrophic Bacteria Count (THBC) revealed that honey wax coating significantly reduced bacterial counts in both carrots and peppers ($p < 0.05$) as shown in fig .1 and fig .2. On day 0, the uncoated carrot had a THBC of 8.8×10^4 CFU/g, while the uncoated pepper had a notably higher THBC of 9.4×10^5 CFU/g. By day 3, coated carrots had a THBC of 9.6×10^4 CFU/g, while coated peppers had a lower count of 4.4×10^5 CFU/g. In contrast, uncoated samples continued to show elevated bacterial growth, with uncoated carrots reaching 2.8×10^4 CFU/g and uncoated peppers 1.0×10^5 CFU/g. ($p < 0.05$). On day 12, coated carrots had a THBC of 1.16×10^5 CFU/g and coated peppers 3.0×10^5 CFU/g, while uncoated samples exhibited excessive spoilage, with counts as high as 6.5×10^4 CFU/g for carrots and 3.1×10^6 CFU/g for peppers. Comparing counts with the regulatory guidelines. US Food and Drug Administration states less than 10^5 cfu/g, European Union states less than or equal to 10^6 cfu/g and International Organization for standardization states less than 10^5 cfu/g for fresh fruit and vegetables, these guidelines are line with this present study.

Staphylococcus counts also exhibited a marked decrease in coated samples ($p < 0.05$) as shown in fig .3 and fig .4. Initially, uncoated carrots had 9.4×10^4 CFU/g, whereas uncoated peppers had a lower count of 8.8×10^3 CFU/g. By day 3, coated carrots had a staphylococcal count of 7.2×10^3 CFU/g, while coated peppers had 6.9×10^3 CFU/g, reflecting

a reduction compared to uncoated samples (9.4×10^3 CFU/g for carrots and 8.8×10^3 CFU/g for peppers). On day 12, the coated carrot samples exhibited staphylococcal counts of 6.9×10^3 CFU/g, while coated peppers showed 4.0×10^3 CFU/g, both significantly lower than uncoated samples ($p < 0.05$). According to the International Commission of Microbiological Specification for fruit and vegetables (ICMSF, 1994 1998) states Total staphylococcus count less than 10^4 cfu/g and Food and Agriculture Organisation of the United Nation states less than 10^5 cfu/g. is acceptable. This guideline corroborates with this study. The coating's efficacy in reducing *Staphylococcus* spp. aligns with previous findings that honey's osmotic effect and hydrogen peroxide release can hinder Gram-positive bacteria, including *Staphylococcus* (Shakila et al., 2016).

Coliform counts further illustrate honey wax's effect on microbial inhibition as shown in fig 5 and .6. On day 0, uncoated carrots had 1.02×10^4 CFU/g, while uncoated peppers had 1.29×10^4 CFU/g. By day 3, coated carrots had reduced coliform counts of 5.6×10^3 CFU/g, and coated peppers had 4.7×10^3 CFU/g. On day 12, the coated carrots exhibited 2.2×10^3 CFU/g, and coated peppers had a slightly higher count of 3.1×10^3 CFU/g, in contrast to uncoated samples, which displayed elevated spoilage. These are slightly higher compared to the findings reported by Pilon et al. (2006). According to the International commission of microbiological specification for food (ICMSF, 1994,1998) reported that coliform of less than 10^2 CFU/g is considered acceptable in fruit and vegetables and Food and Agriculture organization (FAO) of the united nation less than 10^3 cfu/g comparing the count with ICMSF, (1994 .1998), The findings in this study is slightly higher than the acceptable limit. Honey wax coating's impact on coliform counts supports findings by Sapper & Chiralt, (2018), which highlighted that edible coating antimicrobial properties can control coliform growth, thereby enhancing food safety. Differences between carrots and peppers in coliform counts could relate to the nutrient composition, with peppers providing a more conducive environment for coliform bacteria due to higher moisture and sugar levels. Omorodion & Oge (2022).

These results are consistent with those of Zhang et al. (2004), Tanada Palmu et al. (2005), Maftoonazad et al. (2005), Osae (2014), and Nosiba et al. (2018), who all showed a decrease in the microbial count on fresh produce, indicating that the natural antimicrobial qualities of honey wax (edible coating) successfully inhibited bacterial growth. But in a research by Salihah et al. (2023), wax-coated tomatoes showed an even higher decrease in microbial count. Variations in coating composition and application techniques may be the cause of this discrepancy. Due in significant part to its acidity and hydrogen peroxide release, honey's antibacterial properties may work better on produce with a rougher surface, such peppers (Aziz & Karboune, 2018). Additionally, as high-moisture conditions tend to support bacterial development more readily, variations in the vegetable's inherent nutritional and moisture profiles may also lead to varying bacterial growth rates. Additionally, each vegetable has a naturally rough surface; peppers, with their higher water content, may offer bacteria a more favourable environment (Aziz and Karboune,

2018). In a study on effect of agar agar based coating on minimally processed cloves it was observed that filamentous fungus and aerobic mesophilic were inhibited and the coating resulted in reduction of respiration rate of clove Geraldine et al., (2008).

Impact of mango edible film on fresh mango quality and shelf life during storage was evaluated by Sothornvit and Rodsamran (2008) this showed that film provided good oxygen barrier properties and had enough mechanical strength. It also prolonged the shelf life of the mangoes. The impact of modified atmosphere packaging and honey dip treatment as edible coating on minimally processed grapes was evaluated by Sabir Ali et al., (2011). Their study stated that it reduced weight loss of berries. It also maintained the quality of minimally processed grapes by retarding quality loss and berry decay. Result showed that honey dip edible coating act as barrier to moisture and resist to water vapour diffusion during the cold storage and gave good adherence to berry surface and also increase shelf-life.

Effect of coating based on dewaxed shellac and Aloe vera on tomato fruit was evaluated by Chauhan et al., (2015). Their study stated that they contain optimum barrier properties towards O_2 , CO_2 and water vapour and they effectively prevented anaerobiosis. It also prolonged the shelf life of tomatoes. According to Sogvar et al., (2016) studied the impact of edible coating such as aloe vera with ascorbic acid on strawberries. Their study suggested that coating reduced weight loss and inhibiting the growth of mesophilic yeast and molds. This coating enhanced the shelf life of strawberries.

These studies is line with this present study which showed that organisms counts were greater for the coated than with non-coated i.e. control towards the end of storage. The antibacterial activity of the coating and the barrier produced around the cut fruit surface account for the decrease in coated samples. Microbial activity is suppressed by the use of edible coatings on fruits. In this study Honey's acidity, hydrogen peroxide content, and phenolic compounds are key contributors to its antimicrobial action. The wax component further slows microbial access to nutrients by reducing moisture exchange and oxygen permeability, effectively creating an anaerobic environment that inhibits bacterial growth (Becerril-Sánchez et al., 2021)

The morphological and biochemical analysis identified six genera of bacteria *Staphylococcus aureus*, *Micrococcus luteus*, *Bacillus subtilis*, *Serratia merscenscens*, *Escherichia coli*, and *Enterobacter aerogenes* present in both coated and uncoated samples. *Staphylococcus* and *Micrococcus*, frequently found in fresh produce, were the most prevalent genera, occurring in both types of samples across all days. These bacteria is similar to that isolated by Omorodion and Oge, (2022). Similar studies have documented that bacteria such as *Bacillus* and *Escherichia coli* are commonly isolated from raw vegetables and are strongly influenced by the application of protective coatings. For instance, Nunes et al. (2023) observed that edible coatings reduce bacterial populations by creating a physical barrier that reduces moisture loss and limits bacterial adherence. In comparing the bacterial load between carrots and peppers, the study found higher counts in uncoated samples,

likely due to increased surface exposure and nutrient availability Siriwardana and Wijsekara (2021).

Lipid coatings (Bee wax) are good barriers to moisture loss. In addition to preventing water loss, lipid coatings have been used to reduce respiration, thereby extending shelf life, and to improve appearance by generating a shiny product in fruits and vegetables. Coatings that include lipid solids up to 75% can be used to improve coating performance without diminishing moisture-barrier properties (Martin-Polo et al., 1992) The presence of *Enterobacter* and *Serratia* spp., primarily in uncoated samples, suggests that the honey wax coating was effective in reducing these potential spoilage bacteria, a finding consistent with Raybaudi-Massilia et al. (2008), who observed lower spoilage bacteria levels on wax-coated produce.

The frequency of bacterial genera as seen in table 1, showed *Staphylococcus* and *Bacillus* spp. as the most prevalent in both coated and uncoated samples, with *Staphylococcus* accounting for 24.6% and *Bacillus* 24.6% of isolates. Coated samples, however, had notably reduced frequencies, indicating the coating's effectiveness in curbing bacterial presence. Comparable study have shown that wax and honey coatings inhibit bacteria like *Staphylococcus* by acting as a barrier to environmental oxygen, which limits bacterial respiration and growth. Tajik and Jalali (2009).

The presence of *Escherichia coli*, *Staphylococcus aureus*, *Micrococcus luteus*, *Bacillus subtilis*, and *Serratia marcescens* in carrots and green peppers has significant public health implications. These microorganisms can serve as indicators of poor hygiene practices during cultivation, harvesting, storage, or handling. Their potential health risks range from foodborne illnesses to opportunistic infections. *Escherichia coli*, especially pathogenic strains, poses a severe risk of gastrointestinal illnesses, including diarrhea and hemolytic uremic syndrome, if contaminated produce is consumed raw (Malabadi et al., 2024). Its presence often indicates fecal contamination, highlighting inadequate sanitation. *Staphylococcus aureus*, known for producing enterotoxins, can cause food poisoning characterized by nausea, vomiting, and abdominal cramps. Improper storage and temperature abuse can enhance toxin production. *Micrococcus luteus*, although generally non-pathogenic, can be opportunistic, causing infections in immunocompromised individuals. *Bacillus subtilis* is a spore-forming bacterium that can survive harsh conditions. Though typically harmless, it can cause spoilage and foodborne illness through toxin production. *Serratia marcescens*, can cause infections, especially in hospital environments, and may pose risks if transferred from contaminated produce (Caggiano et al., 2021).

The fungal count demonstrated that honey wax coating was also effective against fungal growth as shown in fig 7 and fig 8. Initially, uncoated carrots had a fungal count of 3.0×10^3 CFU/g, and uncoated peppers had a count of 2.2×10^3 CFU/g. By day 3, coated carrots had a reduced fungal count of 1.6×10^3 CFU/g, and coated peppers had 1.4×10^3 CFU/g. On day 12, coated carrots had a fungal count of 1.2×10^3 CFU/g, while coated peppers had 1.8×10^3 CFU/g, with uncoated samples

showing significant fungal proliferation. According to ICMSF and FDA guidelines recommend that fungi count of less than 10^5 CFU/g is considered acceptable in fruit and vegetables. The effectiveness of honey in reducing fungal growth is corroborated by studies that emphasize honey's antifungal action due to its osmotic pressure and low water activity (Mahmud et al., (2015). Differences in fungal counts between carrots and peppers may result from differences in their surface structures and moisture content, which affect fungal adherence and growth rates .Omorodion and Oge (2022).

The study identified *Mucor* sp., *Aspergillus flavus*, *Aspergillus niger*, *Saccharomyces cerevisiae*, and *Alternaria* spp. as the predominant fungi present in both coated and uncoated samples. As shown in table 2, *Aspergillus niger* (31%) and *Aspergillus flavus* (27.6%) were the most frequent. The reduced occurrence of these fungi in coated samples confirms the antifungal efficacy of honey wax, as documented in studies where honey compounds inhibit fungal spore formation Yash Pandya et al. (2023). The frequent presence of *Aspergillus* species, which are common post-harvest fungi, suggests a need for fungal control in produce handling. The honey wax coating likely limited spore germination by reducing oxygen availability and moisture, both critical factors for fungal proliferation (Baldwin et al., 2019). Interestingly, *Aspergillus niger* showed the highest occurrence (31%) among uncoated samples, especially in Green pepper.

The presence of *Mucor* sp., *Aspergillus flavus*, *Aspergillus niger*, *Saccharomyces cerevisiae*, and *Alternaria* sp. in carrots and green peppers has significant public health implications. *Mucor* sp. can cause mucormycosis in immunocompromised individuals. *Saccharomyces cerevisiae*, though used in fermentation, can occasionally cause infections in vulnerable individuals. *Alternaria* spp. produce mycotoxins that may lead to allergic reactions and respiratory issues. *Aspergillus flavus* produces aflatoxins, potent carcinogens linked to liver cancer, while *Aspergillus niger* can cause opportunistic infections and spoilage (Pavon et al., 2012). It was observed that edible coating positively affected shelf life and microbial load in fresh cut fruits. Shelf life of all fresh-cut fruits was significantly enhanced by edible coating.

Physicochemical composition of coated and uncoated carrot and green pepper

The physicochemical analysis on day 0 showed that the uncoated carrot had an ash content of 5.40%, moisture content of 30.4%, lipid content of 0.53%, crude protein of 3.96%, crude fiber of 16.4%, and carbohydrate content of 42.62%. This is lower compared to the findings reported by Omorodion and Oge, (2022). In contrast, uncoated peppers had higher moisture content (80.32%). The lower carbohydrate content (5.5%), reflecting the distinct composition of each vegetable. By day 12, moisture in uncoated carrots dropped to 26.2%, while uncoated peppers reduced to 50.32%, indicating significant dehydration in uncoated samples. This is slightly similar to the findings reported by Omorodion and Oge, (2022). The coated samples, however, retained higher moisture levels (26.6% in carrots and 51.11% in peppers), likely due to the honey wax layer reducing water loss. The stability in ash, crude protein, and carbohydrate content further

highlights the coating's preservation effect, as observed in this study on honey-coated produce.

The vitamin composition of coated and uncoated carrot and green pepper samples highlights the impact of coating on nutrient retention. The uncoated carrot had higher concentrations of Vitamin A (1758.42 µg) and Vitamin B (0.82 µg) compared to the coated carrot (846.19 µg and 0.36 µg, respectively). Similarly, uncoated green pepper exhibited higher Vitamin A (178.45 µg) and Vitamin B (23.76 µg) levels compared to the coated sample (113.96 µg and 14.31 µg, respectively). The findings suggest that coating may inhibit the retention or measurement of these vitamins, potentially due to interactions with the coating material or a barrier effect reducing nutrient exposure.

Conclusion

This study highlights the efficacy of honey wax coatings in extending the shelf life and enhancing the microbial safety of carrots and green peppers. Honey wax effectively reduced microbial counts, including total heterotrophic bacteria, coliforms, and fungi, compared to uncoated samples. By acting as a moisture barrier and antimicrobial layer, honey wax preserved the physical quality of the vegetables, retaining freshness and reducing spoilage over a 12-day period. The coating's effectiveness is attributed to its natural antimicrobial properties, which significantly delayed microbial growth. The results in this study suggest honey wax as a promising, eco-friendly preservative option for perishable produce, especially in settings where refrigeration may be limited. The use of honey wax aligns with consumer demand for natural, non-synthetic food preservation methods. Future research could explore optimizing honey wax formulations and applying them to other types of produce to further validate its preservative potential.

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References

- Aloui, Hand & Khwaldia, K (2016) "Natural antimicrobial edible coatings for microbial safety and food quality enhancement," *Comprehensive Reviews in Food Science and Food Safety*, vol. 15, no. 6, pp. 1080–1103, 2016.
- AOAC (1980), Association of Official Analytical Chemists, Official Method of Analysis 13th edn, Washington, DC U.S.A. pp. 125 - 127. 20.
- Association of Official Analytical Chemist. (2005). *The Official Methods of Analysis*. 18th edition, Washington, D.C. U.S.A., 223-225.
- Association of official analytical Chemist. (2012). *The Official Methods of Analysis*, 19th Ed. AOAC international, Suite 500, 481 North Frederick Avenue, Gaithersburg, Maryland, USA. 20877-2417.
- Aziz M, & Karboune S. (2018) Natural antimicrobial/antioxidant agents in meat and poultry products as well as fruits and vegetables: A review. *Crit Rev Food Sci Nutr.* 11;58(3):486-511. doi: 10.1080/10408398.2016.1194256. Epub 2017 Jun 12. PMID: 27437876
- Aziz M, & Karboune S. (2018) Natural antimicrobial/antioxidant agents in meat and poultry products as well as fruits and vegetables: A review. *Crit Rev Food Sci Nutr.* 11;58(3):486-511. doi: 10.1080/10408398.2016.1194256. Epub 2017 Jun 12. PMID: 27437876.
- Bai J, Robert HD, Elizabeth A, & Baldwin (2003). Coating selection for delicious and other apples. *Postharvest Biology and Tech.* 28:381-390.
- Bai J, Victorine A, Robert, H.D, James. MP, Elizabeth A, M & Baldwin. (2003) Formulation of zein coating for apples (*Malus domestica* Borkh). *Postharvest Bio and Tech.* 28:259-268.
- Baldwin, E. A., Nisperos-Carriedo, M. O., & Hagenmaier, R. D. (2019). Edible coatings to preserve quality and safety of fresh and minimally processed fruits and vegetables. *Postharvest Biology and Technology*, 38(1), 127-132
- Becerril-Sánchez AL, Quintero-Salazar B, Dublán-García O, & Escalona-Buendía HB. (2021) Phenolic Compounds in Honey and Their Relationship with Antioxidant Activity, Botanical Origin, and Color. *Antioxidants (Basel)*. 10(11):1700.
- Bourtoom T. 2008. Review Article: Edible films and coatings: characteristics and properties. *Int. Food Res. J.* 15(3): 237-248
- Caggiano, G., Triggiano, F., Diella, G., Apollonio, F., Lopuzzo, M., Mosca, A. & Montagna, M. T. (2021). A possible outbreak by *Serratia marcescens*: genetic relatedness between clinical and environmental strains. *International journal of environmental research and public health*, 18(18), 9814.
- Chauhan S, Gupta KC, Agrawal M. (2014) Application of biodegradable Aloe vera gel to control post-harvest decay and longer the shelf life of grapes. *Int. J Curr. Microbiol. App. Sci.* 2014; 3:632-642.
- Dhall, R.K. (2013) Advance in edible coating for fresh fruits and vegetables. A Review, *Critical Reviews in Food Science and Nutrition* 53(5):435-450
- Geraldine RM, Soares F, Nilda F, Botrel DA, Goncalves L. de A. (2008) Characterization and effect of edible coatings on minimally processed garlic quality. *Carbo. Polymers.* 72:403-409.
- Giannakourou MC, Tsironi TN. Application of Processing and Packaging Hurdles for Fresh-Cut Fruits and Vegetables Preservation. *Foods*. 2021 Apr 11;10(4):830
- Goldstein J.L., Newbury D.E., Echlin P., Joy D.C., Romig A.D., Lyman C.E., Fiori C., Lifshin E. (1992). *Scanning Electron Microscopy and X-Ray Microanalysis*, 2ed New York: A Division of Plenum Publishing Corporation, pp. 571-599.
- Guilbert S, Gontard N, and Gorris LGM. (1996) Prolongation of the shelf life of perishable food products using biodegradable films and coating. *Lebensmittel Wissenschaft und Technologie*. 29: 10-17
- ICMSF (International Commission on Microbiology Specification for Food). 1994. *Sampling for microbiological Analysis. Principles and Specific Application*, University of Toronto press, Toronto pp 1-18.
- ICMSF. 1998. *Microbial Ecology of Food Commodities. Microorganisms in Foods*. Blackie Academic and Professional.
- Jabeen, S., Gao, X., Altarawneh, M., Hayashi, J. I., Zhang, M., & Dlugogorski, B. Z. (2019). Analytical procedure for proximate analysis of algal biomass: Case study for *Spirulina platensis* and *Chlorella vulgaris*. *Energy & Fuels*, 34(1), 474-482.
- Kotiya, A. & Singh, P. (2023). Applications of Edible Coatings to Extend Shelf-life of Fresh Fruits. In: Malik, J.A., Goyal, M.R., Kumari, A. (eds) *Food Process Engineering and Technology*. Springer, Singapore.
- Kotiya, A., & Singh, P. (2024). Applications of Edible Coatings to Extend Shelf-life of Fresh Fruits. In *Food Process Engineering and Technology: Safety, Packaging, Nanotechnologies and Human Health* (pp. 99-118). Singapore: Springer Nature Singapore.
- Lee JY, Park HJ, Lee CY, & Choi WY* (2003). Extending shelf-life of minimally processed apples with edible coatings and antibrowning agents. *Lebensm.-Wiss. U. Tech.* 36:323-329.
- Lee JY, Park HJ, Lee CY, Choi WY. (2003) Extending shelf-life of minimally processed apples with edible coatings and antibrowning agents. *Lebensm.-Wiss. U. Tech.* 36:323-329.
- Maftoonazad N, & Ramaswamy HS. (2005) Postharvest shelf-life extension of avocados using methyl coating. *LWT*. 38:617-624.
- Mahmud, T., Alhaji S., Dauda, M., Aminu, M., I, Hassan, & Dahiru, M., Naziru. (2015). Study on antifungal activity of honey. *International Journal of Innovation and Scientific Research Vol. 17 No. 2 PP 359 -361.*

- Malabadi, R. B., Sadiya, M. R., Kolkar, K. P., & Chalannavar, R. K. (2024). Pathogenic *Escherichia coli* (*E. coli*) food borne outbreak: Detection methods and controlling measures. *Magna Scientia Advanced Research and Reviews*, 10(1), 052-085
- Martin-Polo M., Voilley A., Blond G., Colas B., Mesnier M., & Floquet N. (1992). Hydrophobic films and their efficiency against moisture transfer. 2. Influence of the physical state. *J. Agric. Food Chem.* 40: 413.
- McHugh T.H., Krochta J.M. (1994). Milk protein based edible films. *Food Technol.* 481: 97-107.
- Nawab A., Alam, F. & Hasnain, A. (2017) Mango kernel starch as a novel edible coating for enhancing shelf life of tomato (*Solanum lycopersicum*) fruit. *International Journal of Biological Macromolecules*, 103: 581-586.
- Nosiba A. Mohammed, Abu-Bakr A. Abu-Goukh and Ali M. Muddathir (2018) Effect of Natural Waxes on Quality and Shelf Life of Tomato (*Solanum lycopersicum* L.) Fruits. *U. of K. J. Agric. Sci.* 26, 18- 35,
- Nunes C, Silva M, Farinha D, Sales H, Pontes R, & Nunes J. (2023) Edible Coatings and Future Trends in Active Food Packaging-Fruits' and Traditional Sausages' Shelf Life Increasing. *Foods*. 2;12(17):3308
- Omorodion, N & Oge, L. (2022). The Influence of Storage Conditions on the Microbial Quality of *Daucus carots* (Carrots) and *Capsicum annum* (Green Pepper). *NASS Journal of Agricultural Sciences*. 4. 36. 10.36956/njas.v4i2.55
- Osae, R. (2014). Assessment of locally produced waxing materials on the shelf-life and fruit quality of two tomato varieties (*Solanum lycopersicum* L.). M. Sc. Thesis, University of Ghana, Ghana.
- Pavon, M. A., Gonzalez, A. I., Martín, R & Lacarra, T. (2012). The importance of genus *Alternaria* in mycotoxins production and human diseases. *Nutrición hospitalaria : organo oficial de la Sociedad Española de Nutrición Parenteral y Enteral*. 27. 1772-81.
- Pilon, L., Spricigo, P.C., de Britto, D., Assis, O.B.G., Calbo, A.G., Ferraudo, A.S. and Ferreira, M.D. (2013) 'Effects of antibrowning solution and chitosan-based edible coating on the quality of fresh-cut apple', *Int. J. Postharvest Technology and Innovation*, Vol. 3, No. 2, pp.151-164.
- Pomeranz, Y. (1971), *Food Analysis Theory and Practice*; an West Port Publisher, 145-149
- Prasad K., A. K. Guarav, P. Preethi, P. & Neha. (2018) Edible coating technology for extending market life of horticultural produce. *Acta Scientific Agriculture*, 2(5): 55-64.
- Raybaudi-Massilia R M, Mosqueda-Melgar J, Soliva-F R, & Martín-Belloso O (2009) Control of Pathogenic and Spoilage Microorganisms in Fresh-cut Fruits and Fruit Juices by Traditional and Alternative Natural Antimicrobials. *Compr Rev Food Sci Food Saf.* 8(3):157-180.
- Riva, S.C, Opara, U.O, & Fawole, O.A. (2020). Recent developments on postharvest application of edible coatings on stone fruit: A review. *Scientia Horticulturae* 262: 109074.
- Sabir A, Sabir F.K, & Kara, Z (2011). Effects of modified atmosphere packing and honey dip treatments on quality maintenance of minimally processed grape cv. Razaki (*V. vinifera* L.) during cold storage. *J Food Sci Tech.* 4:312-318.
- Salihah Ibrahim, Wan & Rudiyanto, Rudiyanto & Shah, Ramisah M.. (2023). Effect of edible beeswax coating on tomato (*Solanum lycopersicum*) postharvest quality. *E3S Web of Conferences*. 444.
- Sapper, M., & Chiralt, A. (2018). Starch-Based Coatings for Preservation of Fruits and Vegetables. *Coatings*, 8(5), 152.
- Shakila, R.J.; Jeevithan, E.; Arumugam, V. & Jeyasekaran, G (2016). Suitability of antimicrobial grouper bone gelatin films as edible coatings for vacuum-packaged fish steaks. *J. Aquat. Food Prod. Technol.* 25, 724-734.
- Shi, D., Zhao, B., Zhang, P. *et al.* (2024). Edible composite films: enhancing the postharvest preservation of blueberry. *Hortic. Environ. Biotechnol.* 65, 355-373
- Siriwardana, J, and Wijesekara, I, (2021) Analysis of the Effectiveness of an Antimicrobial Edible Coating Prepared from Sweet Whey Base to Improve the Physicochemical, Microbiological, and Sensory Attributes of Swiss Cheese, *Advances in Agriculture*, 5096574, 13 pages.
- Sogvar OB, Saba MK, Emamifard A. (2016) Aloe vera and ascorbic acid coatings maintain postharvest quality and reduce microbial load of strawberry fruit. *Postharvest Biology and Technology*. 2016; 114:29-35.
- Sothornvit R. & Rodsamran P. (2008) Effect of a mango film on quality of whole and minimally processed mangoes. *Postharvest Biology and Tech.* 47:407-415
- Tajik H, & Jalali FSS (2009). In vitro Evaluation of antimicrobial efficacy of natural honey comparison with sulfonamide derivatives. *J. Anim. Vet. Adv.* 8:23-25.
- Tanada-Palmu P.S, & Grosso, C.R.F (2005). Effect of edible wheat gluten-based films and coatings on refrigerated strawberry (*Fragaria ananassa*) quality. *Postharvest Bio. and Tech.* 36:199-208.
- Tavassoli-Kafrani E., H. Shekarchizadeh, M. & Masoudpour-Behabadi. (2016) Development of edible films and coatings from alginates and carrageenans. *Carbohydrates Polymers*, 137: 360-374.
- Teshome, E., Forsido, S.F., Rupasinghe, H., Vasantha, P & Keyata, E., (2022). Potentials of Natural Preservatives to Enhance Food Safety and Shelf Life: A Review. *The Scientific World Journal*
- Valero, Daniel & Díaz-Mula, Huertas & Zapata, Pedro & Guillén, Fabián & Martínez-Romero, Domingo & Castillo, S. & Serrano, María. (2013). Effects of alginate edible coating on preserving fruit quality in four plum cultivars during postharvest storage. *Postharvest Biology and Technology*. 77. 1-6. 10.
- Wan Nur Salihah H., Wan I., Rudiyanto, I., & Ramisah, M. S (2023) Effect of edible beeswax coating on tomato (*Solanum lycopersicum*) postharvest quality. *E3S Web of Conferences* 444 04010 IConARD 2023
- Yaman O., & Bayoindirli L. (2002) Effects of an edible and cold storage on shelf life and quality of cherries. *Lebensm. Wiss. Und. Technol.* ; 35:146-150.
- Yash P, Anushka S & Manish B (2023) Edible Coatings in Fruits: Effectiveness and Applicability: A Review *FoodSci: Indian Journal of Research in Food Science and Nutrition*, Vol 10(1), 01-10
- Zhang M, Xiao G, Luo G, Peng J, & Salokhe VM. (2004) Effect of coating treatments on the extension of the shelf-life of minimally processed cucumber. *Int Agrophysics*. 18:97-102