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RESEARCH PAPER

EFFICIENCY OF EDIBLE COATING FROM LOCALLY SOURCED MATERIALS IN MAINTAINING THE POSTHARVEST QUALITY OF BELFAST TOMATOES

Oduro K.O.A.[1]*, Boakye A.A.[1], Oduro I.N.[1], Peprah-Ameyaw N.B[2], Ellis W.O.[1]

[1]*Department of Food Science and Technology, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.*
[2]*Department of Food Science, Chapman University, Orange-California, USA*

***Corresponding Author: kofiowusu.oduro@gmail.com**

ABSTRACT
Edible coating technology has been proven to be an efficient and effective method of postharvest preservation. Especially in developing countries, edible coatings and other postharvest technologies are often limited by their high cost. The study aimed to assess the effect of edible coating materials prepared from inexpensive and locally available materials on the postharvest quality of Belfast tomatoes during storage. Different edible coating formulations [M1, M2, M3 and M4] were prepared by varying the concentration of orange peel powder [OP] [0,0.1,0.5,1%] in 10g/L Cassava Starch [CS] and 10g/L Chitosan [CH] coating solutions. Coated and control fruits were stored at 25°C for three weeks. Results showed that the coatings significantly [p<0.05] delayed the changes in weight loss, total Soluble solids, pH and colour compared to uncoated control fruits. At the end of the 3-week storage period, the control fruits recorded the highest weight loss, 25.58 ±1.73 % whiles M4 had the least, 15.14 ±0.30 %. M4 [CH+CS+1OP] significantly maintained the total soluble solids of the tomatoes which increased from 5.71° to 6.68°whiles the control tomatoes increased from 5.71° to 9.09° showing the effectiveness of the coating in maintaining the Total Soluble Solid (TSS) of the Belfast tomatoes. The coated samples also showed some resistance to the colour changes as well as the pH exhibiting the ability to delay the ripening rate in the tomatoes. The edible coating significantly improved the postharvest quality of the Belfast tomato and could have immense impact on other local tomato varieties.

Keywords: Edible Coating, Belfast Tomato, Postharvest Quality, Chitosan, Cassava Starch

INTRODUCTION

In Sub-Saharan Africa, an estimated 40% of all food crops are lost before they get to the consumers, leaving only 60% of the produce which is not enough to satisfy their demands [Chakraborty, 2011]. During periods of glut, postharvest losses reach unprecedented levels because of the lack of proper storage conditions to preserve the food products. Aidoo *et al* [2014] reports that farmers undergo a lot of financial losses due to significant quantitative and qualitative losses along the food chain which deprives consumers of much-needed nutrition and nourishment. Several postharvest technologies have been employed that influence the intrinsic and extrinsic factors including moisture content, temperature, relative humidity, respiration rate, microbial and enzymatic activity thereby impacting the postharvest quality of fresh food products [Oduro, 2021]. Biswas *et al [*2016] asserts that some causes of postharvest losses of fresh foods include high moisture loss, enzymatic activity, high respiration rates, microbial activity and high temperatures which speed up senescence and spoilage reactions. Among the several postharvest technologies available, edible coating has been shown as an effective novel postharvest technology that has varied applications in various food products [Yadav *et al*.,2022].

According to recent studies, it may be possible to reduce food waste and by-products using waste and by-product-derived natural materials in food packaging as the next eco-conscious step of waste valorization [Tumwesigye *et al.,* 2016]. The availability of functional packaging material could therefore reduce global pollution caused by microplastics. Antioxidant compounds from food waste can be incorporated into packaging materials to improve the safety and shelf life of food products. The unique characteristics of food packaging produced from fruit and vegetable wastes and by-products make them of great interest as it could provide many benefits, including antioxidant properties, antimicrobial properties, and improved mechanical properties. These wastes have been incorporated into edible films and coating, active packaging systems, smart packaging systems, and biopolymers for improved packaging properties [Salgado *et al.*, 2015].

Edible coating is an eco-friendly and effective method of preservation for various fresh food products whereby it modifies the atmosphere around the fresh food products by acting as a barrier to moisture, gases and solutes [Jose *et al*.,2020]. According to Aguirre-Joya *et al*., [2016], edible coatings and films are rapidly being integrated into the food processing industries for the preservation of fresh food products such as fruits, vegetables and some dairy products. Edible coatings are developed from various biopolymer matrices such as polysaccharides e.g. chitosan, starch alginate, pectin and pullulan, proteins such as gelatin, collagen, corn zein and casein, and lipid-based materials such as paraffin wax, rice bran wax and jojoba oil [Valdes *et al*., 2015]. The coatings can be applied by spraying, dipping and brushing method to obtain a thin protective layer [Yousuf *et al*., 2018].

The molecular structure, rather than the molecular size and chemical composition, determines the properties of edible coating [Dhall,2013]. It also determines their barrier properties with respect to water vapour, oxygen and carbon dioxide in food systems. For fresh fruits such as tomatoes, edible coatings work by reducing the respiration rate of the fruits disrupting the ethylene production, thus slowing down the ripening process as well as minimizing physiological loss of water [Dhall, 2013].

Edible coatings and other postharvest technologies are often limited by their high cost, especially in developing countries. Though these methods of preservation are very effective, their cost-intensive nature defeats the purpose of producing fresh food products at an affordable price to make them accessible to all consumers as well as becoming utterly unbearable for smallholder farmers which make them less utilized in their farms in these developing countries. Dhall [2013] reports that commercially available edible coatings are expensive and thus it is important to investigate locally available materials as sources of alternative and relatively affordable edible coatings for fresh food products.

In Ghana, tomato production is an antidote for widespread unemployment and poverty for most households, particularly in the Upper East Region of Ghana [Melomey et al, 2022]. Tomato is classified as a functional food since it is an excellent source of vitamins and minerals as well as beneficial phytochemicals such as polyphenols and lycopene which provide a wide variety of health benefits including valuable antioxidant, anti-inflammatory and anti-cancer properties [Canene-Adams *et al*., 2005]. Despite these benefits, several physical and biological factors contribute to tomato's perishability, including transpiration, ethylene production, high respiration rate, and microbial attack [Ayomide *et al*., 2019]. Nunes [2008] asserts that quality is combination of attributes or properties that gives each commodity value in terms of human food. In the tomato industry, quality is tested and observed in terms of colour, firmness, Total soluble solids, Titratable Acidity and pH. These attributes are constantly undergoing changes [increase or reductions] which significantly impact the quality of the tomatoes which lead to deterioration. Tomatoes are usually harvested at different ripening stages depending on the consumer preferences. Particularly for the fresh market, Kasim *et al*., [2015] confirms that the texture, flavour and colour are one of the most important quality attributes for tomatoes which also influences its marketing value. Thus, control of these changes could potentially improve upon the shelf-life as well as improve the marketing value of the tomatoes.

Research into the use of edible coating materials which are generally regarded as safe [GRAS], eco-friendly, easy to apply and cost-effective, can help to significantly reduce the levels of postharvest losses and increase accessibility to consumers [Oduro, 2021]. The aim of this work is to evaluate the effect of different formulations of an edible coating containing chitosan, cassava starch and orange peel powder on the postharvest quality of the Belfast tomato variety. There have been several reports that orange peel contains essential oils which have great antimicrobial and antioxidant properties [Dubey *et al.,* 2011; Rashidi *et al.,* 2021; Vaishali *et al.*, 2018]. This work will provide an alternative edible coating composition made of inexpensive and locally available ingredients.

MATERIALS AND METHODS

Materials and Sample Preparation

Belfast tomato variety [Figure 1] was obtained from the KNUST greenhouse at pink stage of ripening according to the USDA standard tomato colour classification chart. Orange samples were obtained from the Ayeduase market in the Ashanti region, Ghana. The orange powder was prepared according to the method used by Rani *et al*., [2020]. Oranges acquired from the market were thoroughly washed and peeled. The fruits peel was cut into small pieces and Sun-dried for 48 hours. The dried peel was converted into fine powder form and packed in an airtight plastic container for further use.

Giant African snail shells [Figure 2] were collected from the Kejetia market. They were cleaned, washed and sun-dried for 24 hours They were then ground into powder using a hammer mill.

***Fig 1:** Belfast tomatoes*

***Fig 2:** Giant African Snail Shells*

Chitosan Production from Giant African Snail Shells

Chitosan was produced from Giant African Snail shells according to the procedures described by Bello et al [2021]. First, the prepared Giant African snail shells powder was weighed with an analytical balance to a specific mass. The deproteinization was carried out by using 2M NaOH with a ratio of 1g:10ml [w/v] at room temperature. The treatment was carried out for two hours. A mechanical stirrer was used throughout the process. After two hours, the solution was washed with water and filtered until it had a neutral pH. The residue from deproteinization was dried using the oven drier and weighed with an analytical balance. Demineralization was carried out with dilute 2 M HCl solution. The sample was treated with 2M HCl with a ratio of 1g:10ml [w/v] at a room temperature. The treatment was carried out for two hours whiles constantly stirring using a mechanical stirrer. The solution was then washed and filtered severally until a neutral pH was achieved. The residue was dried using the oven drier and weighed with analytical balance. Then, it underwent deacetylation with 50% NaOH with ratio of 1g: 10ml [w/v] at 100°C for 3 hours. The solution was then filtered and washed till it attained a neutral pH. The residue was then dried and weighed using the analytical balance.

The chitosan yield [%] was calculated using the given formula:

Chitosan yield [%] = (Weight of chitosan)/(Weight of Chitin)×100 1

A flowchart on the production of the chitosan can be observed in Figure 3.

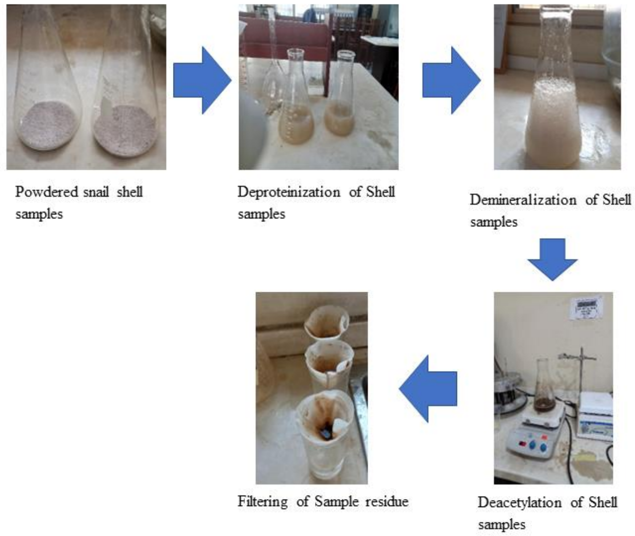

Fig 3: *Flowchart for Chitosan production*

Preparation of Edible Coatings

Four formulations of edible coating were prepared as described by Araujo *et al*. [2018], using 10g/L Cassava Starch [CS] and 10 g/L Chitosan [CH]. Four coating solutions were prepared as an orange-peel powder [OP] was added separately at [0,0.1,0.5,1.0] % concentrations for the treatments M1 [CS+CH], M2 [CS+CH+0.1 OP], M3 [CS+CH+ 0.5 OP] and M4 [CS+CH+ 1 OP] respectively according to the method described by Al-Anbari *et al.,* [2019]. Chitosan was dissolved [w/v] in acetic acid solution [0.26 mol/L] and glycerol [12.8g/L] was then added, to complete the volume to 100mL. A cassava starch solution [100mL] was prepared in glycerol [6.4 g/L]. The starch solution was stirred in a heated water bath at 70 °C. After cooling to 25°C, the solution was added to the chitosan solution and stirred until it was completely homogenous. Then the different percentages of the orange powder were added to the mixtures for the different formulations.

Application of Edible Coatings on Tomatoes

The selected tomatoes were sanitized by dipping tomatoes in sodium hypochlorite solution for 15 min, rinsed with water and dried at room temperature. Then, groups of 10 tomatoes were immersed in each formulation for 1 min, the control tomatoes were also dipped in pure distilled water also for 1 min. The treated tomatoes were then dried at room temperature for 30 min. The physical-chemical properties of tomatoes were determined once every week for three weeks during the day.

Weight Loss

For determining the weight loss, the fruit was weighed at weeks 1, 2 and 3 of storage on a weighing scale (mention type, brand and manufacturing country of scale). The total weight loss was calculated as a percentage of the initial weight [Ali *et al*., 2010].

$$\text{Weight loss [\%]} = (\text{Initial weight} - \text{Final weight}) / (\text{Initial weight}) \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; 2$$

Colour Parameters

Superficial colour alterations were monitored using a Konica Minolta Inc chromameter CR-410 made in Japan. The international commission on illumination [CIE 1986 [colour parameters, a* [redness], b* [yellowness] and L* [luminosity], were directly recorded on the surface of the tomatoes. Each sample was homogenized and analyzed using the Chromameter to determine the colour parameters.

pH, Titratable Acidity and Total Soluble Solids [TSS] Analysis

Three tomatoes from each coating group and the control were homogenized and the pH for every one of them was recorded using a Mettler Toledo pH meter.

The titratable acidity was measured using 5g of the tomato juice and 25ml of deionized water, with 0.1NaOH as the titrant, and the results expressed as g citric acid /kg as described by Bassetto *et al*., [2005].

The total soluble solids [TSS] were determined for each of the tomato fruit samples, using a Soonda bench refractometer and expressed as %.

Statistical Analysis

The differences in the physical and chemical parameters for tomato samples coated with five formulations of the edible coating were determined by analysis of variance [ANOVA] and least significant difference test [LSD] (Mention specific software used). Statistical significance was determined at $p < 0.05$.

RESULTS AND DISCUSSION

Percentage Yield of Chitosan

The yield of various products obtained at various stages of extraction are tabulated in Table 1.0 below. The final chitin and chitosan masses achieved were 16.2197g and 4.247g respectively. This chitosan yield is very low compared to the chitosan yield from snail shells where Oyekunle and Omoleye [2019] achieved a chitosan yield of 39.69%. This can be attributed to the difference in the composition of the shells of the different varieties of snails used. Other sources of chitosan such as the crab shell as reported by Pambudi *et al*., [2018], had /a chitosan yield of 84.34%. The lowest percentage yield in the different steps in the methodology was the demineralization stage [8.64%]. This is because mollusc shells are known to have significant levels of minerals such as phosphates and calcium [Alabaraoye *et al.*, 2018]. This caused a significant decrease in the mass of the shell samples and thus a lower yield.

The stage that achieved the highest yield however was the deproteinization stage [92%]. This is because the deproteinization stage deals with the removal of residual proteins from shells. This usually yields a greater percentage of products because the shells contain very little residual protein.

Table 1.0: **Yield of Chitosan(%) from Giant African Snail**

Method	g	%
Giant Snail shells powder	200	
Stage 1 + 2 (Deproteinization and Demineralization)		
%wt of Chitin	16.2197	8.10985
Stage 3 (Deacetylation)		
% wt of Chitosan	4.2476	26.1879

Weight loss of Belfast Tomato fruits

The effect of Chitosan [CH] -Cassava Starch [CS] coating incorporated with orange peel powder [OP] on the cumulative weight loss of tomato fruits is shown in Figure 4. Weight loss of all fruits increased with elapsed storage time. After three weeks of storage, weight losses of 25.58 ± 3.44 % for the control and 23.49 ± 1.43%, 17.76 ±1.11%, 21.50 ±1.56% and 15.14 ± 0.70% for M1 [CH + CS], M2 [CH + CS + 0.1 OP], M3 [CH + CS + 0.5 OP] and M4 [CH + CS + 1 OP] respectively were recorded. The rate of weight loss in control fruits was rapid compared to coated fruits.

It can be observed that all edible-coated tomatoes had a lower weight loss as compared to the control. The weight loss can be seen to increase gradually during the storage period for all the tomato samples. From fig 4, it can be observed that the control tomatoes had the highest weight loss after week 2 and 3 of storage. The M4 [CH + CS + 1 OP] coated tomato had the lowest weight loss among the treatments from the graph. Coating treatment and storage time significantly affected the weight loss of the fruits. During the first two weeks of storage, the weight losses of M4 [CH + CS + 1OP] and M3 [CH + CS + 0.5 OP] tomato treatments and the control fruits differed significantly [$p<0.05$]. However, M2 [CH + CS + 0.1 OP] and M1 [CH + CS] showed no significant differences in the weight losses recorded.

The weight loss recorded for M4 at the end of the three weeks storage period was significantly lower ($p<0.05$) than the weight loss recorded for the control.

This indicated that M4 treatment was most effective in reducing weight loss and showed impressive characteristics in maintaining the weight loss especially within the first two weeks of storage. Ali *et al*., [2010] assert that the basic mechanism of weight loss from fresh fruit produce is by vapour pressure at different locations. It is due to higher transpiration of water which reduces the postharvest quality and organoleptic properties of fruits and vegetables. The reduction of weight loss in the treated tomatoes can be attributed to the fact that the coating creates a semi-permeable barrier against oxygen, moisture and solute movement thereby reducing water loss.

Results revealed that the application of the chitosan-cassava edible coating formulations minimized the weight loss of tomatoes at 28°C. This was achieved by the coating creating a barrier against gas exchange and water transpiration. This study agrees with a study by Mani *et al*., [2017] where he stated that edible coating reduced the physiological loss in weight of fruits during storage due to the retarded rate of respiration, controlled enzymatic reaction and delayed utilization of respiratory materials such as organic acids. Results also agree with findings by Sucharitha *et al*., [2018] and Zam [2019].

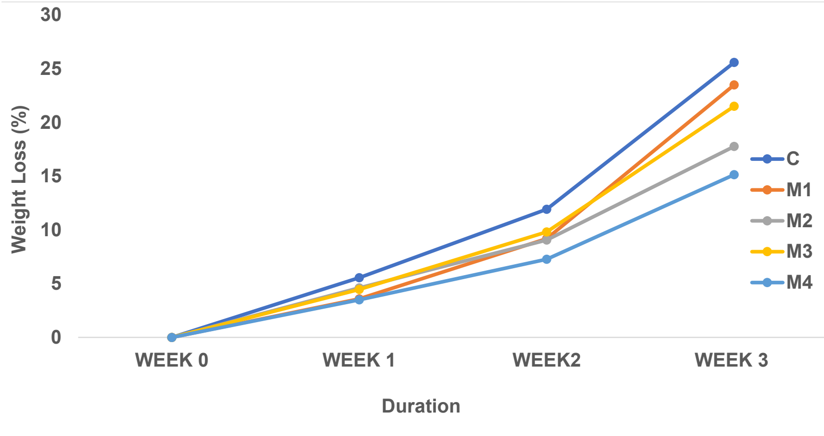

Fig 4: *Weight loss of Belfast tomato during storage (28°C, 50-60% RH) for three weeks*

C [control fruits], M1 [CH + CS], M2 [CH + CS + 0.1 OP], M3 [CH + CS + 0.5 OP] and M4 [CH + CS + 1OP]

4.3 Total Soluble Solids [TSS] of Belfast Tomato

The effect of Chitosan [CH] – Cassava Starch [CS] coating incorporated with orange peel powder [OP] on the Total soluble solid content of Belfast tomato fruits are presented in Figure 5. The results show a general increase of the TSS in stored tomatoes irrespective of treatments from the first week and the second week and a decrease in the third week of storage.

The increase in the TSS as observed in fig 5 agrees with findings by Teka [2013] who reported that the increase in the TSS content is caused by the breakdown and conversion of the complex to simple sugars during storage. The increase of the TSS is usually higher at room temperature than at cold temperature [Kumar *et al.*, 2021]. The control tomato samples recorded the highest TSS values among the samples as the coated samples showed remarkable ability to slow down ripening process in the tomatoes by slowing down the breakdown of the complex metabolites to simple sugars. The control tomatoes exhibited higher TSS values after week 1 [7.47±0.26° Brix] and week 2 [9.09± 0.29° Brix] whereas all treated tomatoes had quite lower Brix values as compared to the control after week 1 and week 2 of storage. M1 [CH + CS] increased from 6.5± 0.47° after the first week to 7.97± 0.26° in the second week. M2 [CH + CS + 0.1 OP] was also observed to increase from 6.5± 0.35° to 7.97± 0.17° from the first week to the second week. M3 [CH + CS + 0.5 OP] also increased from 6.87± 0.32° to 8.22± 0.06° from the first week to the second week. M4 [CH + CS + 1 OP] increased from 6.37± 1.03° to 6.68± 0.60° after the first week to second week of storage. The results indicated that M4 significantly maintained the total soluble solids after the 2 weeks of storage.

The statistical analysis also showed that all the samples except for M4 had a significant change [$p<0.05$] indicating that the M4 coated tomato had better controlled changes in the TSS [%] as compared to the control and other treatment groups. In general, it was observed that the change in TSS content in tomatoes treated with Chitosan [CH] -Cassava starch [CS] with the orange peel powder [OP] coating was lower compared to the control sample.

The total soluble solids were seen to decrease after the third week of storage. This result is in accordance with the findings by Sree *et al*., [2020] where they reported after the 20th day of storage, the lowest TSS value in 2.5% chitosan coated tomatoes. This can be attributed to the action of microbes and further breakdown of sugars to other metabolic products. The sugars in the tomato produced during ripening are converted to other metabolites such as ethanol, acetone, succinate and other products [Doran-Peterson et al, 2008]. The results of the study are in line with earlier work by Hossain and Iqbal [2014]. Previous studies have shown that the total soluble solids in different varieties of tomatoes differ; for instance, the TSS value for beefsteak tomatoes range from 3-5% whiles that for cherry tomatoes range from 5-7% [Luengwilai *et al*., 2010a]. The total soluble solids influence the flavour of the tomatoes which affects its marketability as well. Thus, the ability of the edible coatings to significantly control the changes in the TSS during the three weeks shows that it would be able to improve the shelf-life as well as sustain its marketability value on the market as the flavour will be retained longer as compared to the control tomatoes.

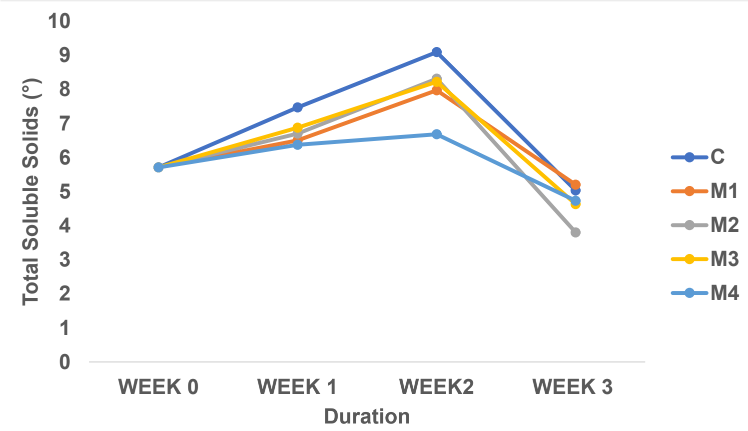

***Fig 5**: TSS changes in Belfast tomato during storage (28°C, 50-60% RH)*

C [control fruits], M1 [CH + CS], M2 [CH + CS + 0.1 OP], M3 [CH + CS + 0.5 OP] and M4 [CH + CS + 1OP]

pH of Belfast Tomato

The effect of chitosan-cassava starch coating incorporated with orange peel powder on the pH of Belfast tomato are shown in Figure 6. pH of all the sample groups were seen to increase as the storage period progressed.

The M3 treatment group was shown to have the highest pH after Week 3 of storage while M4 showed the least increase in the pH throughout the storage period. The control tomato had an increase from 4.27 to 4.54 from the first week to the third week whiles that for the M4 tomatoes had a pH of 4.30 after week 3, which was significantly($p<0.05$) lower than the control. The results show that the variety used shows some excellent resilience in delaying the respiration rate as compared to other varieties studied. For instance, Xiang *et al*., [2021] observed that the pH of cherry tomato samples increased from 4.20 to 4.60 during storage. Again, in agreement with that study, the sample pH was not significantly affected by the type of coating applied though M4 showed some level of resistance among the other coating formulations used. The increase in pH is due to the organic acid which provides most of the hydrogen ions in tomatoes and normally decreases with ripening resulting in an increase in pH due to its usage in various metabolic activities as the storage duration increases [Tigist *et al.,* 2013].

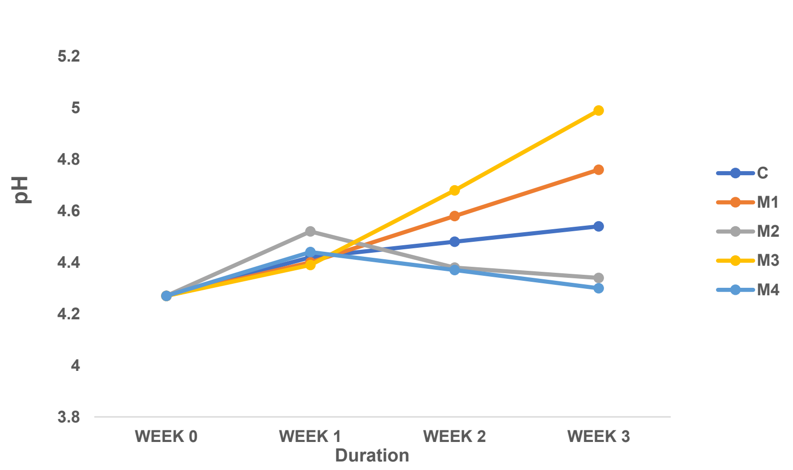

Fig 6: *pH of Belfast tomato during storage (28°C, 50-60% RH) for three weeks.*

C [control fruits] ; M1 [CH+CS]; M2 [CH+CS+ 0.1OP]; M3 [CH+CS+0.5OP] and M4 [CH+CS+1OP]

Titratable Acidity [TA] of Belfast Tomato

The effect of Chitosan [CH] – Cassava Starch [CS] coating incorporated with orange peel powder [OP] on the Titratable Acidity of Belfast tomato is shown in Figure 7. The titratable acidity was seen to decrease in all the treatment groups.

There was no significant difference [$p<0.05$] between coated and uncoated samples at the end of the period of storage. However, M4 and M2 had the highest TA values which were 0.40% and 0.30% as compared to M1 and M2 which also had 0.3072 and 0.2517 respectively.

The control samples also had a TA value of 0.2816% showing a significant decrease in the Titratable Acidity value from the first week of storage. Vigneault *et al*., [2012] established that chitosan coated samples had higher titratable acidity than uncoated samples because the coatings reduced the respiration rate, thereby slowing down the consumption of organic acids as a respiratory substrate. The same results were observed in a study by Raffo *et al*., [2006] which shows the acidity decreased with maturation. According to Das *et al*., [2013], the decrease in the acidity of the tomatoes over time seems more pronounced in uncoated tomatoes.

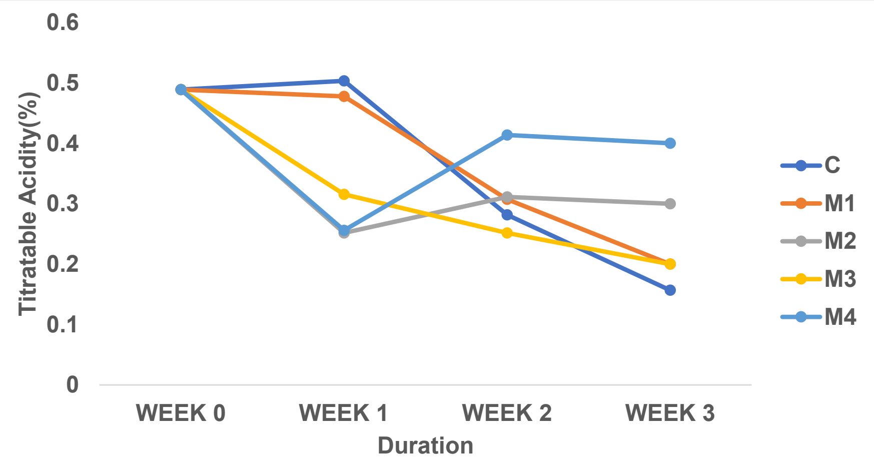

Fig 7: *Titratable Acidity [%] of Belfast tomato fruits during storage (28°C, 50-60%) for three weeks of storage.* **C [control]; M1 [CH+CS]; M2 [CH+CS+0.1OP]; M3 [CH+ CS +0.5OP]; M4 [CH+CS+1OP].**

Colour Changes in Belfast Tomato

The effect of Chitosan [CH] – Cassava Starch [CS] coating incorporated with orange peel power [OP] on the colour changes of the Belfast tomato during storage is shown in Fig 8.

It can be generally seen that both control and coated samples showed some changes in the L*. The L* values for the control in the first week was 42.27± 0.54 whiles the coated samples M1, M2, M3 and M4 were 41.03±1.11, 41.74±1.17, 42.34±3.22 and 42.36±0.95 respectively. It can be observed that as the storage time increased the L* for both the control and the coated samples reduced. This is because as the red colour pigment continues to be synthesized, there is a decline in the L* value. This result agrees with findings made by Sahlin *et al*., [2004]. There was no significant difference in the L* values for the control samples and the coated samples. This can be because of the impressive characteristics of the tomato variety used as other varieties used gave much lower L* values after the 20th day of storage. For instance, a finding made by Athmaselvi et al [2013] indicated that the L* values reduced from 43.56 on the first day to 27.05 on the 20th day. This shows that the variety used can retain its light colour for a longer period than other tomato varieties.

The a* values to red colour were seen to increase exponentially for all the tomato samples showing an increase in the redness of the tomato. After the third week of storage, the control samples had the highest a* value, 27.17 which was significantly different from the a* value recorded for M3, 11.7517 showing the effectiveness of the coating to slow the increase of the redness of the tomato. This resulted in the reduction of the respiration rate and ripening rate of the tomato samples. This result agrees with the findings made by Athamaselvi et al [2013] where he found out that application of Aloe Vera to the fruits was able to slow down the increase in the a* values. The increase in the redness of the tomato is caused by the increase in the lycopene content and further degradation of the chlorophyll content in the tomatoes Kasim *et al*., [2015] assert that the carotenoids present in tomatoes such as lycopene and beta carotene are responsible for the deep red and orange colours which also influence the quality perception of these fresh tomatoes. Slowing down the reddening of the tomatoes indicates a longer marketability value for tomatoes since the tomatoes could last longer on the market as they gradually attain their fully red state.

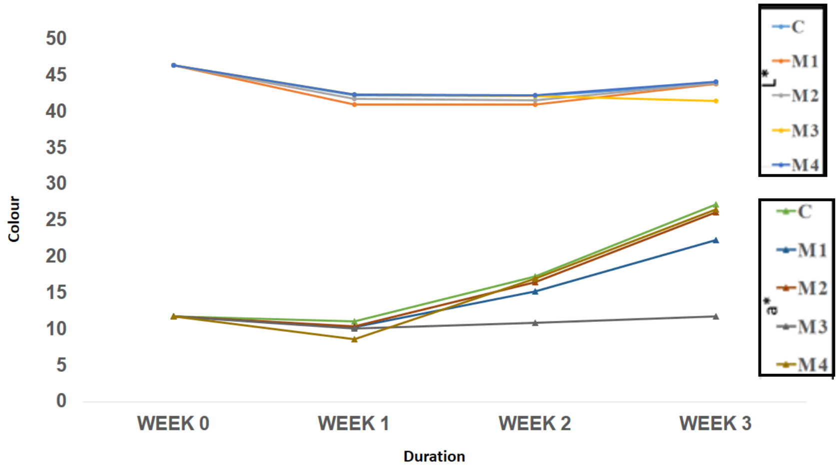

Fig 8: *L * and a** **Colour changes of Belfast Tomato coated with Chitosan [CH] – Cassava Starch [CS] coating incorporated with orange peel powder [OP] during storage**

C [control]; M1 [CH+CS]; M2 [CH+CS+0.1OP]; M3 [CH+ CS +0.5OP]; M4 [CH+CS+1OP]

CONCLUSIONS

The coatings studied showed varying effects on the postharvest quality of the tomato fruits. The impact of the chitosan-cassava starch and orange peel composite coating was able to reduce the weight loss and changes in the pH, TSS and in the titratable acidity as well as delaying colour changes during storage. The M4 coated tomato had a significant impact in the reduction of weight loss while M3 also showed much resistance in the changes in the TSS during storage. The tomato variety used, Belfast was seen to possess some good qualities that made the control tomatoes quite resilient and possess some good postharvest qualities during the storage period. This shows that application of this coating on other local varieties can significantly improve its postharvest qualities. Again, improvement of this variety can improve its commercialization and enhance its shelf life. Edible coating is a viable option to consider in reducing postharvest losses considering access to its raw materials which could be from food wastes as well as its effectiveness in improving the postharvest quality of fresh fruits.

RECOMMENDATION

Some recommendations from this study are as follows;

There should be a thorough biochemical analysis on the properties of the Belfast tomato as these findings show it's a potentially superb variety to solve the issues of tomato postharvest losses

There should be further studies on the optimization of the coatings to produce edible films which can be used to preserve the fruit as well as other fresh fruit products

There should be analysis on the sensory properties of the tomatoes after coating to ascertain its impact on the sensorial properties of the tomato

There should be further studies on the impact of the edible coating on the tomato during processing to find out whether or not it helps to retain some nutrients or essential components in the food material.

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DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial or personal relationships that could have appeared to influence the work in this paper.

REFERENCES

Aguirre-Joya, J.A., Álvarez, B., Ventura, J.M., García-Galindo, J.O., De León-Zapata, M.A., Rojas, R., Saucedo, S. and Aguilar, C.N., 2016. Edible coatings and films from lipids, waxes, and resins. Edible food packaging: materials and processing technologies, pp.121-152.

Aidoo, R., Danfoku, R.A. and Mensah, J.O., 2014. Determinants of postharvest losses in tomato production in the Offinso North district of Ghana. Journal of development and agricultural economics, 6(8), pp.338-344

Al-Anbari, I.H., Dakhel, A.M. and Adnan, A., 2019. The effect of adding local orange peel powder to microbial inhibition and oxidative reaction within edible film component. Plant Arch, 19, pp.1006-1012.

Ali, A., Maqbool, M., Ramachandran, S. and Alderson, P.G., 2010. Gum arabic as a novel edible coating for enhancing shelf-life and improving postharvest quality of tomato [Solanum lycopersicum L.] fruit. Postharvest biology and technology, 58[1], pp.42-47.

Alabaraoye, E., Achilonu, M. and Hester, R., 2018. Biopolymer [Chitin] from various marine seashell wastes: isolation and characterization. Journal of Polymers and the Environment, 26[6], pp.2207-2218.

Araújo, J.M.S., de Siqueira, A.C.P., Blank, A.F., Narain, N. and de Aquino Santana, L.C.L., 2018. A cassava starch–chitosan edible coating enriched with Lippia sidoides Cham. essential oil and pomegranate peel extract for preservation of Italian tomatoes [Lycopersicon esculentum Mill.] stored at room temperature. Food and Bioprocess Technology, 11[9], pp.1750-1760.

Athmaselvi, K.A., Sumitha, P. and Revathy, B.J.I.A., 2013. Development of Aloe vera based edible coating for tomato. International Agrophysics, 27[4].

Ayomide, O.B., Ajayi, O.O. and Ajayi, A.A., 2019, December. Advances in the development of a tomato postharvest storage system: Towards eradicating postharvest losses. In Journal of Physics: Conference Series [Vol. 1378, No. 2, p. 022064]. IOP Publishing.

Bassetto, E., Jacomino, A.P., Pinheiro, A.L. and Kluge, R.A., 2005. Delay of ripening of 'Pedro Sato'guava with 1-methylcyclopropene. Postharvest Biology and Technology, 35[3], pp.303-308.

Bello, V.E. and Olafadehan, O.A., 2021. Comparative investigation of RSM and ANN for multi-response modeling and optimization studies of derived chitosan from Archachatina marginata shell. Alexandria Engineering Journal, 60(4), pp.3869-3899.

Biswas, P., East, A.R., Hewett, E.W. and Heyes, J.A., 2016. Chilling injury in tomato fruit. Horticultural reviews, 44, pp.229-278.

Canene-Adams, K., Campbell, J.K., Zaripheh, S., Jeffery, E.H. and Erdman Jr, J.W., 2005. The tomato as a functional food. The Journal of nutrition, 135[5], pp.1226-1230.

Chakraborty, S. and Newton, A.C., 2011. Climate change, plant diseases and food security: an overview. Plant pathology, 60(1), pp. 2-14.

Das, D.K., Dutta, H. and Mahanta, C.L., 2013. Development of a rice starch-based coating with antioxidant and microbe-barrier properties and study of its effect on tomatoes stored at room temperature. LWT-Food Science and Technology, 50[1], pp.272-278.

Dhall, R.K., 2013. Advances in edible coatings for fresh fruits and vegetables: a review. Critical reviews in food science and nutrition, 53[5], pp.435-450.

Doran-Peterson Joy, Dana M. Cook, Sarah K. Brandon [2008].. Microbial conversion of sugars from plant biomass to lactic acid or ethanol. The Plant Journal. 54: 582-592

Dubey, D., Balamurugan, K., Agrawal, R.C., Verma, R. and Jain, R., 2011. Evalution of antibacterial and antioxidant activity of methanolic and hydromethanolic extract of sweet orange peels. Recent Research in Science and Technology, 3(11).

Hossain, M. S.; Iqbal, A. Production and characterization of chitosan from shrimp waste. J. Bangladesh Agric. Univ. 2014, 12, 153– 160, DOI: 10.3329/jbau.v12i1.21405

Jose, A., Pareek, S. and Radhakrishnan, E.K., 2020. Advances in Edible Fruit Coating Materials. In Advances in Agri-Food Biotechnology [pp. 391-408]. Springer, Singapore.

Kasim Mehmet Ufuk and Kasim Rezzan [2015]. Postharvest UV-B treatments increased fructose content of tomato [Solanum Lycopersicon L. cv. Tayfun F1] harvested at different ripening stages. Food Sci. Technol. 35[4]: 742-749.

Kumar, N., Tokas, J., Raghavendra, M. and Singal, H.R., 2021. Impact of exogenous salicylic acid treatment on the cell wall metabolism and ripening process in postharvest tomato fruit stored at ambient temperature. International Journal of Food Science & Technology, 56[6], pp.2961-2972.

Luengwilai, K., Tananuwong, K., Shoemaker, C. F., & Beckles, D. M. [2010a]. Starch molecular structure shows little association with fruit physiology and starch metabolism in tomato. Journal of Agricultural and Food Chemistry, 58[2], 1275-1282

Mani, A., Jain, N., Singh, A.K. and Sinha, M., 2017. Effects of aloevera edible coating on quality and postharvest physiology of ber [Zizyphus Mauritiana Lamk.] under ambient storage conditions. Int. J. Pure App. Biosci, 5[6], pp.43-53.

Melomey, L.D., Ayenan, M.A., Marechera, G., Abu, P., Danquah, A., Tarus, D. and Danquah, E.Y., 2022. Pre-and post-harvest practices and varietal preferences of tomato in Ghana. Sustainability, 14(3), p.1436.

Nunes, N. MC (2008). Color atlas of postharvest quality of fruits and vegetables.Experimental Agriculture. 45(1). Pp. 463

Oduro, K.O.A., 2021. Edible coating. Postharvest Technology-Recent Advances, New Perspectives and Applications.

Oyekunle, D.T. and Omoleye, J.A., 2019, August. New process for synthesizing chitosan from snail shells. In Journal of

Physics: Conference Series [Vol. 1299, No. 1, p. 012089]. IOP Publishing.

Pambudi, G.B.R., Ulfin, I., Harmami, H., Suprapto, S., Kurniawan, F. and Ni'mah, Y.L., 2018, December. Synthesis of water-soluble chitosan from crab shells [Scylla serrata] waste. In AIP Conference Proceedings [Vol. 2049, No. 1, p. 020086]. AIP Publishing LLC.

Raffo, A., La Malfa, G., Fogliano, V., Maiani, G. and Quaglia, G., 2006. Seasonal variations in antioxidant components of cherry tomatoes [Lycopersicon esculentum cv. Naomi F1]. Journal of Food Composition and Analysis, 19[1], pp.11-19.

Rani, V., Sangwan, V. and Malik, P., 2020. Orange peel powder: A potent source of fiber and antioxidants for functional biscuits. Int. J. Curr. Microbiol. Appl. Sci, 9, pp.1319-1325.

Rashidi, M., Mansour, S.S., Mostashari, P., Ramezani, S., Mohammadi, M. and Ghorbani, M., 2021. Electrospun nanofiber based on Ethyl cellulose/Soy protein isolated integrated with bitter orange peel extract for antimicrobial and antioxidant active food packaging. International Journal of Biological Macromolecules, 193, pp.1313-1323.

Salgado, P.R., Ortiz, C.M., Musso, Y.S., Di Giorgio, L. and Mauri, A.N., 2015. Edible films and coatings containing bioactives. Current Opinion in Food Science, 5, pp.86-92.

Sahlin, E., Savage, G.P. and Lister, C.E., 2004. Investigation of the antioxidant properties of tomatoes after processing. Journal of Food composition and Analysis, 17[5], pp.635-647.

Sree, K.P., Sree, M.S. and Samreen, P.S., 2020. Application of chitosan edible coating for preservation of tomato. IJCS, 8[4], pp.3281-3285.

Sucharitha, K.V., Beulah, A.M. and Ravikiran, K., 2018. Effect of chitosan coating on storage stability of tomatoes [Lycopersicon esculentum Mill]. International Food Research Journal, 25[1], pp.93-99.

Teka, T.A., 2013. Analysis of the effect of maturity stage on the postharvest biochemical quality characteristics of tomato (Lycopersicon esculentum Mill.) fruit. International Research Journal of Pharmaceutical and Applied Sciences, 3(5), pp.180-186.

Tigist, M., Workneh, T.S. and Woldetsadik, K., 2013. Effects of variety on the quality of tomato stored under ambient conditions. Journal of food science and technology, 50, pp.477-486.

Tumwesigye, K.S., Oliveira J.C. and Sousa-Gallagher, M.J [2016]. New sustainable approach to reduce cassava borne environmental waste and develop biodegradable materials for food packaging applications. Food Packag. Shelf Life. 7 pp 8-19.

Valdés, A., Burgos, N., Jiménez, A. and Garrigós, M.C., 2015. Natural pectin polysaccharides as edible coatings. Coatings, 5[4], pp.865-886.

Vaishali, M. and Geetha, R.V., 2018. Antibacterial activity of orange peel oil on Streptococcus mutans and Enterococcus-An In-vitro study. Research Journal of Pharmacy and Technology, 11(2), pp.513-514.

Vigneault, C., Leblanc, D.I., Goyette, B. and Jenni, S., 2012. Invited review: Engineering aspects of physical treatments to increase fruit and vegetable phytochemical content. Canadian Journal of Plant Science, 92[3], pp.373-397.

Xiang, F., Xia, Y., Wang, Y., Wang, Y., Wu, K. and Ni, X., 2021. Preparation of konjac glucomannan based films reinforced with nanoparticles and its effect on cherry tomatoes preservation. Food Packaging and Shelf Life, 29, p.100701.

Yadav, A., Kumar, N., Upadhyay, A., Sethi, S. and Singh, A., 2022. Edible coating as postharvest management strategy for shelf-life extension of fresh tomato (Solanum lycopersicum L.): An overview. Journal of Food Science, 87(6), pp.2256-2290.

Yousuf, B., Qadri, O.S. & Srivastava, A.K. [2018]. Recent developments in shelf-life extension of fresh-cut fruits and vegetables by application of different edible coatings: A review. LWT - Food Science and Technology, 89, 198–209.

Zam, W., 2019. Effect of alginate and chitosan edible coating enriched with olive leaves extract on the shelf life of sweet cherries [Prunus avium L.]. Journal of Food Quality.