ACTA SCIENTIARUM POLONORUM
Acta Sci. Pol. Technol. Aliment. 22(1) 2023, 43–55
www.food.actapol.net pISSN 1644-0730 eISSN 1898-9594 http://dx.doi.org/10.17306/J.AFS.2023.1092

ORIGINAL PAPER

Received: 21.09.2022
Accepted: 4.01.2023

# IMPROVEMENT OF SHELF-LIFE AND NUTRIENT QUALITY OF TOMATOES AND EGGPLANT FRUITS USING CHITOSAN-STARCH COMPOSITE COAT

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## ABSTRACT

**Background.** In developing countries like Nigeria, postharvest loss of fruits and vegetables have been a serious problem as they become unavailable outside their peak seasons due to poor preservation techniques.
**Methods.** This study evaluated the improvement of the storage-life and nutrient retention of tomato and eggplant fruits via the application of chitosan-starch edible coat. The dip coating method was used to coat the fruit samples while standard procedures (AOAC methods) were applied in determining the shelf-life and nutrient quality of the fruit samples.
**Results.** The results of the shelf-life study showed that the coated fruits were still fresh at day 12 of storage. A significant change in protein, fiber and carbohydrate content was observed for coated tomato (5.34, 3.2 and 26.55%, respectively) compared to the uncoated tomato (24.8, 11.4 and 62.77% respectively). There was a significant difference between the change in ascorbic acid content in coated (6.28%) and uncoated (17.11%) eggplant. In tomato fruit, a significant difference existed in the ascorbic acid content of the coated (0.59%) and uncoated (7.46%) fruit, as well as the beta-carotene level (0.81 and 7.98%, respectively).
**Conclusion.** It is therefore noteworthy that edible chitosan–starch composite coating may be instrumental in curbing the challenges of fruit deterioration with concomitant retention of nutrients.

**Keywords:** coat, storage life, tomato, eggplant, chitosan, cassava

## INTRODUCTION

Fruit and vegetables that have been harvested can be compared to live systems that are actively undergoing metabolism. As a result, a range of spoilage bacteria, as well as enzymatic and chemical processes, can cause them to deteriorate (Petruzzi et al., 2017). This may pose a significant risk to the health of consumers and accrue heavy financial losses to producers, as consumers may withdraw their support and patronage. Foodborne disease is a public health issue that encompasses a wide range of disorders, the most common of which is gastroenteritis, which may be caused by a variety of microorganisms such as bacteria, viruses and

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parasites (Majumdar et al., 2018). As a result of these microbial infestations and other forms of postharvest spoilage, most fruit and vegetables are only transiently available after their peak seasons. Examples of such fruits are garden egg plants and tomato fruits.

Garden egg (*Solanum melongena*) is a versatile crop that may be cultivated all year round and is suitable to many agro-climatic areas. This plant belongs to the solanacaea family's genus solanum L. and is one of the most widely grown crops (Han et al., 2021). In certain West African countries, the utilization of *Solanum melongena* fruits is equivalent to that of tomatoes, however tomatoes and garden eggs are utilized as complements rather than alternatives. Although eggplants can withstand more stress than tomatoes, they are still prone to physical damage, as well as infestations of pathogens such as *Enterobacter* spp., *Salmonella* spp., *E. coli*, *Listeria monocytogenes*, *Penicilium* spp., *Aspergillus* spp. among others (Nasiru and Dahatu, 2020).

Fresh tomatoes (*Lycopersicon esculentum*) are one of the most famous agricultural produces globally. They are very much appreciated for their vast utilization, as well as their health-related benefits. Tomatoes contain a large reserve of vital compounds like ascorbic acid, carotenoids, flavonoids and phenolic acids, among others (Zhang et al., 2017). Meanwhile, this fruit is seasonal as a result of its short postharvest storage time, which may be implicated on the grounds of the rate of transpiration and the degree to which it ripens (because of light skin). Tomatoes are very fragile and cannot withstand a lot of physical stress else the outer skin will break and become infested with microorganisms. Postharvest loss for tomato fruits on an annual global scale can be estimated to be 42% (Arah et al., 2015). Therefore, it is necessary to find an effective method for preservation in order to maintain tomato fruits' shelf-life quality.

The losses that accrue from deteriorated fruit and vegetables as well as the outbreak of microbial related foodborne diseases have prompted researchers to look for new techniques to help maintain food quality, freshness and safety while preventing microbial growth. Several preservation procedures have been studied to prevent the deterioration of fresh fruit and vegetables in order to improve their shelf life (De Corato, 2020). A few examples of these are low temperature and high relative humidity, controlled and modified atmospheric packing, chemical preservatives, canning and the use of plastic films. Each of these methods has its own set of benefits and drawbacks. The drawbacks might include economic consequences, particularly in underdeveloped nations, rise in antibiotic resistance among some diseases (Dadgostar, 2019) and disposal issues, all of which are severe public and environmental concerns.

Recent research has focused on overcoming these limitations, prompting the development of alternative preservation approaches, such as edible coatings for the development of an internal modified environment (Corbo et al., 2015; Firouz et al., 2021). An edible coating/film is a thin continuous layer of edible material that is formed on or between food and food components (Oduro, 2021). Edible coatings are being applied and built directly on the surface of food products, which are then ingested with the food material. The use of edible films or coats which are designed from ecologically friendly materials aid delayed ripening, color changes, controlled water loss and decay, as well as enhanced attractiveness (Sharma et al., 2019). Features such as biocompatibility, biodegradability, bioactivity and non-toxicity of polymers of polysaccharide chitin and its deacetylated derivative — chitosan — has become more popular because of its potential use in agriculture, biomedicine and biotechnology, as well as the food sector (Parveen et al., 2019). Chitosan is a linear polymer composed of β-(1→4)-linked 2-amino-2-deoxy-D-glucose residues generated from a deacetylated derivative of chitin, which is the second most abundant polysaccharide in nature after cellulose (Peter et al., 2021). The sources of chitosan and the procedures used to extract them have an impact on their physicochemical characteristics and functions (Aranaz et al., 2021; Iber et al., 2022).

Eggplant and tomato fruits are abundant at peak seasons in tropical regions like Nigeria, but shortly become scarce. Over time, this has exacerbated the cost of these fruits for the poor masses. The present study was therefore aimed at developing a low-cost preservative method (edible composite chitosan-cassava starch-based coat) for the extension of shelf life and retention of nutrient quality of garden egg and tomatoes.

## MATERIALS AND METHODS

### Materials

The chitosan used in this study was obtained from Wisapple Biotech. Co., Ltd, Beijing while cassava

tubers were purchased from the Ultra-Modern Market Minna, Niger State, Nigeria.

## Methods

**Starch extraction from cassava tuber.** The tubers of cassava were peeled, sliced into little chunks and were soaked for 24 hours in water. The soaked cassava was then mashed into a slurry after the solution had been decanted. The slurry was filtered using a muslin cloth and thoroughly washed with distilled water. After 6 hours, the supernatant was decanted from the filtrate and the settled starch layer, resuspended in distilled water and centrifuged for 10 minutes at 2800 rpm. The starch was collected and dried at 50°C in an oven (Hasmadi et al., 2021).

**Preparation of composite coat.** The casting procedure and dehydration of the suspension solution in petri plates was carried out, as reported in the study of Ossamulu et al. (2021). The suspension solution was made by dissolving (1% w/v) chitosan in 100 mL of aqueous acetic acid solution at 2% (v/v). Under controlled heating circumstances (80°C) and constant stirring on a hot plate magnetic stirrer (Macro Scientific Works, India), cassava starch powder (0.5% w/v) was added to the chitosan solution until the gelatinization temperature was reached. Afterwards, 0.3% glycerol was added to the mixture and agitated for another 30 minutes to ensure thorough mixing and the eradication of bubbles. The resultant solution was filtered through a cheese cloth to remove undissolved components and allowed to cool before being used to coat the fruits (Fig. 1).

**Evaluation of shelf life of coated fruits.** At room temperature, the fresh fruit samples (tomato and eggplant) were entirely immersed in the coating solution. They were allowed to drain before being forced air dried at room temperature to generate a thin film coating on the fruit. The fruits were weighed and kept at room temperature and the trials were repeated. Fruits that were not coated served as control, and were kept in the identical conditions as the coated fruits. The physiological loss in weight (PLW) and other proximate characteristics of the fruits were measured at 3-day intervals for the tomato fruit and 5-day interval for the garden eggs.

**Physiological loss in weight (PLW) of the studied fruits.** Water loss was calculated in terms of physiological loss in weight by the equation:

$$\frac{A - B}{A} \times 100$$

Where, A is the initial weight of fruits and vegetables (0 day) and B is the fruit weight after the storage period.

**Nutrient composition of fruit samples.** The nutritious components of the samples (moisture, total ash, crude fiber, and fat) were measured in triplicate using the Association of Analytical Chemists (AOAC,

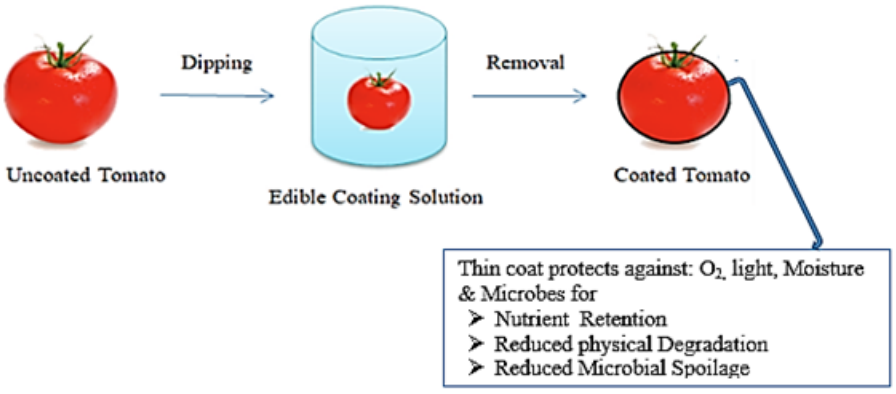


**Fig. 1.** Dip coating method

2005). The nitrogen content was measured using the micro Kjeldah technique, and the nitrogen content was multiplied by a factor of 6.25 to convert it into protein. The total carbohydrate content was calculated using the 'difference' method. Percentages were used to report all the determined proximate analyses.

**Determination of ascorbic acid content in the fruit and vegetable samples.** Ascorbic acid was determined calorimetrically as reported by El Sharaa and Mussa (2019). In 25 ml of 4% oxalic acid solution, the sample (2 g) was pulverized with a pestle and mortar. The liquid was collected after centrifuging, filtering and centrifuging the resultant material. Bromine water was added drop by drop to an aliquot (10 ml) in a conical flask with steady mixing. Excess bromine in the extract caused it to become orange yellow, which was subsequently evacuated by blowing in air. A 4% oxalic acid solution was used to make 25 milliliter (25 ml) solution. In the same vein, through bromination, a 10 mL stock of ascorbic acid solution was made into the dehydro-form. A standard dehydroascorbic solution (1–100 mg) was pipetted into a series of tubes. Separate aliquots of brominated sample of the extract (0.1–2 ml) were pipetted into different containers as well, and 3 ml of distilled water was added to all the tubes. To each tube, 1 ml dinitrophenylhydrazine (DNPH) reagent was added, followed by 2 drops of thiourea. A blank solution was prepared replacing only ascorbic acid with distilled water while other contents were maintained in the same amount, thoroughly mixed, then incubated for 3 h at a temperature of 37°C. The crystals that developed (orange-red colour) throughout the incubation process were solubilized using 7 ml of 80% sulphuric acid. A calibration curve was generated from the absorbance (measured at 540 nm) of the standard ascorbic acid. The concentration of ascorbic acid in the fruit was determined by extrapolating on the standard curve.

**Determination of total carotenoid content in the fruit and vegetable samples.** Two grams of the fruit sample were pulverized in acetone solution with a mortar and pestle. The mixture (250 ml) was poured into a conical flask and extraction proceeded with acetone until the residue became colourless. After that, the extract was thoroughly combined with 15 ml of pet ether in a separatory funnel. By diluting acetone with water that contains 5% sodium sulphate, the solution with yellow pigment was then turned into the petroleum ether. Continual additions of petroleum ether were made until the color was transferred to the petroleum ether layer. At 460 nm, the color intensity was measured. The findings were measured in milligrams of beta-carotene per 100 grams of material (Sahabi et al., 2012).

### Data analysis

Results were expressed as mean ± standard error of mean of triplicate determinations. Data obtained were subjected to analysis of variance (ANOVA) followed by post-hoc Duncan Multiple Range Test (DMRT) for separating the means using SPSS version 23.0. The level of significance was accepted at $p < 0.05$.

## RESULTS AND DISCUSSION

Table 1 shows the changes in weight of coated and uncoated fruits (eggplant and tomato) for a period of twelve (12) days. The weights of both coated and uncoated fruits decreased as the storage time increased. Coated eggplant fruit had weights ranging from 18.33 ±0.41 g at day 0 to 17.58 ±0.51 g at day 12 while the coated tomato's weight ranged from 38.57 ±0.27 g to 37.94 ±0.81 g at days 0 and 12 respectively with the weight only significantly lower at day 12 of storage. The coated eggplant weight at days 9 and 12 were significantly ($p < 0.05$) lower than at days 0, 3 and 6. Uncoated eggplant showed significant progressive decrease in weight from day 6 to 12. A similar trend was observed for the uncoated tomato samples.

Figure 2 shows the physical changes in uncoated and coated tomato, as well as eggplant fruit, during the storage time. Days 6, 9 and 12 showed visible wrinkle, more wrinkle and spoilage spot on the surface of the uncoated tomato (control) while the coated tomato fruit remained fresh even after the 12th day. The uncoated eggplant showed patches of spoilage on the 12th day of storage whereas the coated eggplant fruit was still fresh even after the 12th day.

The percentage weight change in coated and uncoated fruits (eggplant and tomato) is presented in Figure 3. Uncoated eggplant and tomato had significantly ($p < 0.05$) higher % change in weight (8.30 and 5.30%

**Table 1.** Physiological weight (g) of coated and uncoated fruit samples stored over a period of time

| Samples | Time, days 0 | 3 | 6 | 9 | 12 |
|---|---|---|---|---|---|
| | | | UCF | | |
| Eggplant | 17.78 ±0.12$^{d}$ | 17.50 ±0.14$^{d}$ | 17.04 ±0.03$^{c}$ | 16.69 ±0.25$^{ab}$ | 16.34 ±0.47$^{a}$ |
| Tomato | 40.13 ±2.63$^{c}$ | 39.86 ±1.07$^{c}$ | 39.72 ±1.88$^{bc}$ | 38.89 ±1.18$^{b}$ | 37.88 ±1.05$^{a}$ |
| | | | CF | | |
| Eggplant | 18.33 ±0.11$^{c}$ | 18.31 ±0.06$^{c}$ | 18.26 ±0.05$^{c}$ | 17.95 ±0.02$^{a}$ | 17.58 ±0.51$^{a}$ |
| Tomato | 38.57 ±0.27$^{b}$ | 38.53 ±0.08$^{b}$ | 38.48 ±0.32$^{b}$ | 38.45 ±1.13$^{ab}$ | 37.94 ±0.01$^{a}$ |

Values are represented as mean ±SEM of triplicate determinations.
Value with different alphabets along a row are significantly ($p < 0.05$) different.

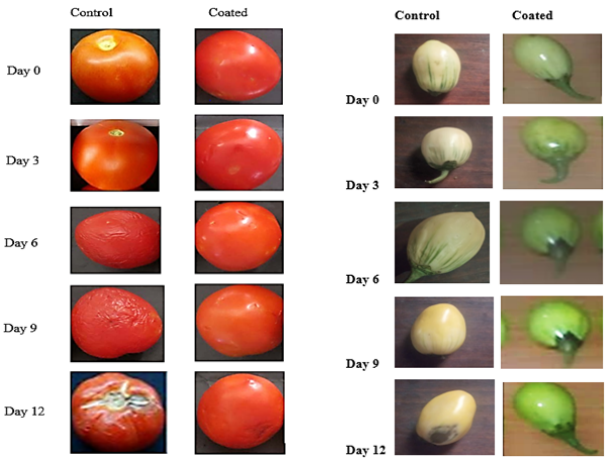


**Fig. 2.** Changes in tomato and garden egg fruit during the storage time

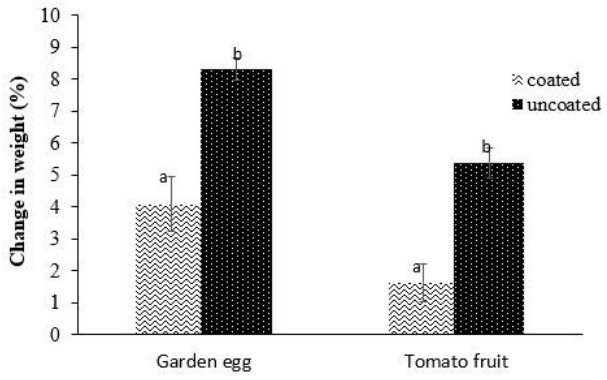


**Fig. 3.** Physiological change in weight (%) of fruits

respectively) compared to the coated samples (4.09 and 1.63% respectively). However, eggplant had significantly ($p < 0.05$) higher weight change than tomato in both coated and uncoated forms.

The proximate composition of coated and uncoated eggplant is shown in Table 2. The moisture content of coated and uncoated eggplant decreased as storage time increased; however, it was only significantly ($p < 0.05$) lower at day 12 for the coated sample. Protein, fiber and ash contents of the uncoated eggplant were all significantly lower only at the 12$^{th}$ day compared to the other days of storage. Although, in the coated eggplant fruit, protein, crude fibre and fat contents were not significantly different at days 9 and 12 of storage, while no significant difference was observed for ash concentration all through the time of storage. The crude fat content of coated eggplant at day 12 was observed to be significantly lower than in days 0, 3 and 6. The level of carbohydrate in uncoated eggplant increased significantly ($p < 0.05$) with the increasing storage time, whereas vitamin C concentration decreased significantly with increasing storage time. The carbohydrate content of coated eggplant increased progressively but was only significantly higher at day 12, while vitamin C concentration was significantly higher at days 0 and 6.

Figure 4 depicts the difference in nutritional content (percentage) between the coated and uncoated eggplant samples. Uncoated eggplant samples had a much larger percentage change in moisture content (9.83 ±0.34%) than coated eggplant samples (3.63

**Table 2.** Nutrient composition of coated and uncoated eggplant over the storage time

| Parameters, % | Time, days | | | | |
|---|---|---|---|---|---|
| | 0 | 3 | 6 | 9 | 12 |
| | | | Uncoated | | |
| Moisture | 89.44 ±0.01$^{d}$ | 89.04 ±0.07$^{d}$ | 86.75 ±0.13$^{c}$ | 82.80 ±0.51$^{b}$ | 80.64 ±0.12$^{a}$ |
| Protein | 2.02 ±0.04$^{c}$ | 2.15 ±0.00$^{c}$ | 1.83 ±0.22$^{bc}$ | 1.70 ±0.05$^{b}$ | 1.52 ±0.10$^{a}$ |
| Fibre | 3.35 ±0.11$^{c}$ | 3.30 ±0.11$^{c}$ | 3.18 ±0.05$^{bc}$ | 3.06 ±0.05$^{b}$ | 2.46 ±0.20$^{a}$ |
| Crude fat | 0.29 ±0.03$^{bc}$ | 0.25 ±0.01$^{b}$ | 0.24 ±0.00$^{b}$ | 0.20 ±0.03$^{a}$ | 0.18 ±0.02$^{a}$ |
| Ash | 0.37 ±0.15$^{b}$ | 0.39 ±0.11$^{b}$ | 0.41 ±0.01$^{b}$ | 0.42 ±0.02$^{b}$ | 0.33 ±0.01$^{a}$ |
| Carbohydrate | 4.52 ±0.07$^{a}$ | 4.86 ±0.13$^{b}$ | 7.59 ±0.27$^{c}$ | 11.82 ±1.43$^{d}$ | 14.87 ±1.65$^{e}$ |
| Vitamin C | 1.87 ±0.03$^{d}$ | 1.80 ±0.01$^{c}$ | 1.69 ±0.04$^{b}$ | 1.65 ±0.07$^{b}$ | 1.55 ±0.07$^{a}$ |
| | | | Coated | | |
| Moisture | 88.29 ±0.01$^{bc}$ | 88.18 ±0.13$^{b}$ | 88.07 ±0.15$^{b}$ | 87.11 ±0.21$^{ab}$ | 85.08 ±0.10$^{a}$ |
| Protein | 1.87 ±0.03$^{b}$ | 1.88+0.01$^{b}$ | 1.84 ±0.01$^{b}$ | 1.82 ±0.06$^{ab}$ | 0.71 ±0.04$^{a}$ |
| Fibre | 3.21 ±0.31$^{b}$ | 3.20 ±0.11$^{b}$ | 3.14 ±0.12$^{b}$ | 3.09 ±0.17$^{ab}$ | 2.91 ±0.05$^{a}$ |
| Crude fat | 0.32 ±0.02$^{b}$ | 0.30 ±0.01$^{b}$ | 0.31 ±0.03$^{b}$ | 0.28 ±0.02$^{b}$ | 0.24 ±0.02$^{a}$ |
| Ash | 0.41 ±0.01$^{a}$ | 0.41 ±0.00$^{a}$ | 0.40 ±0.01$^{a}$ | 0.43 ±0.02$^{a}$ | 0.41 ±0.02$^{a}$ |
| Carbohydrate | 5.90 ±0.03$^{a}$ | 6.03 ±0.15$^{ab}$ | 6.23 ±0.16$^{ab}$ | 7.25 ±0.81$^{ab}$ | 9.58 ±0.24$^{c}$ |
| Vitamin C | 1.91 ±0.01$^{b}$ | 1.88 ±0.00$^{a}$ | 1.89 ±0.03$^{b}$ | 1.83 ±0.01$^{a}$ | 1.79 ±0.02$^{a}$ |

Values are represented as mean ±SEM of triplicate determinations.
Value with different alphabets along a row are significantly ($p < 0.05$) different.
Vitamin C in mg/100 g.

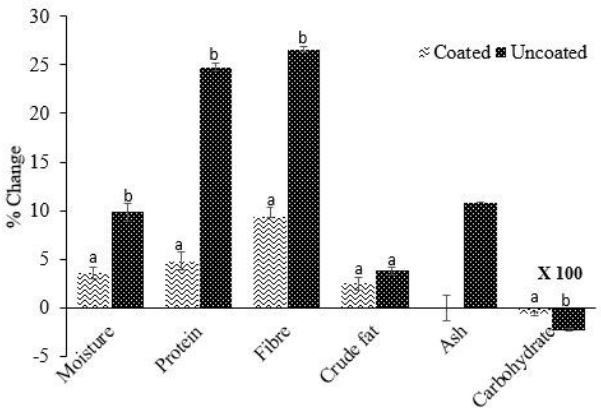


**Fig. 4.** Percentage change in nutrient composition of coated and uncoated eggplant

±0.27%). Similarly, the percentage change in protein content was significantly ($p < 0.05$) higher in the uncoated eggplant sample (24.75 ±1.04%) compared to the coated (4.81 ±0.42%). The % reduction in crude fiber and fat contents in the coated eggplant sample were 9.34 ±0.87 and 25.0 ±1.75% respectively. However, the uncoated sample showed a % reduction of 26.56±2.11 and 37.93 ±1.95%, respectively. There was no reduction in the ash content of coated eggplant although, the uncoated sample had a 5.40 ±0.27% reduction. For coated eggplant sample, carbohydrate content increased by 38.41 ±3.12%, while a 69.60 ±2.86% increase was observed for the uncoated eggplant. The ascorbic acid content of coated and uncoated eggplant was shown in Figure 5. Through the period of storage, the coated eggplant sample had

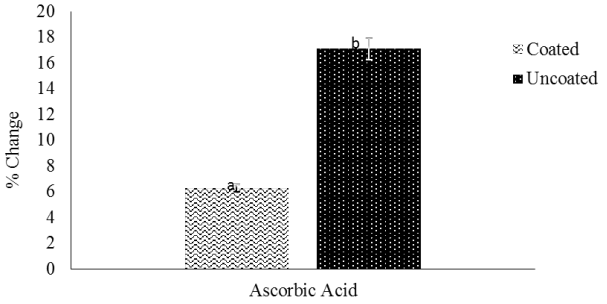


**Fig. 5.** Percentage change in ascorbic acid (vitamin C) content of coated and uncoated eggplant

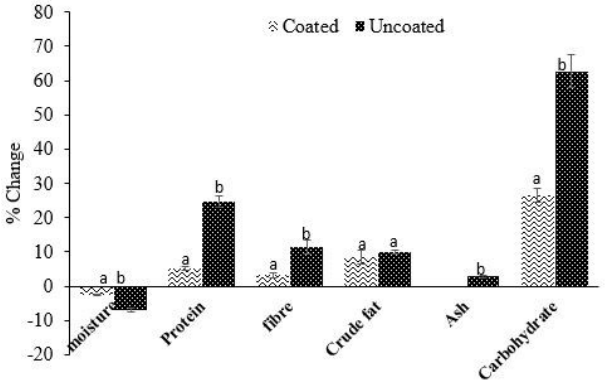


**Fig. 6.** Percentage change in nutrient composition of coated and uncoated tomato fruit

a 6.28 ±0.55% reduction in vitamin C content, which was significantly ($p < 0.05$) lower than the 17.11 ±1.06% loss from uncoated eggplant sample.

Table 4 shows the nutrient composition of coated and uncoated tomato fruit at an interval of three days, over a twelve days period. The uncoated tomato fruit showed a time dependent significant increase in moisture level across the storage time, while similar progression was observed for the coated samples although not significant through the storage period. The protein and fiber contents of coated tomato were observed to decrease with increasing storage time. However, there was no significant ($p > 0.05$) difference in the concentrations of these nutrients through the storage period. The crude fat content of coated tomato was not significantly ($p > 0.05$) different through the storage period, while a significant difference was observed for crude fat through the storage period. Ash content in the coated and uncoated tomato samples was not significantly ($p > 0.05$) different with time of storage. A progressive (days 0 to 12) significant decrease in carbohydrate content was observed in uncoated and coated tomato fruit except that the latter was not significantly ($p < 0.05$) different at days 9 and 12.

Figure 6 shows the effect of coating on the nutrient content of tomato on the basis of the nutrient percentage change (between initial and final storage period). The moisture content increased for uncoated tomato, although a 7.08 ±0.56% increase was observed for uncoated, compared to 2.55 ±0.31% for the coated tomato. The uncoated tomato sample had 24.80 ±1.56% protein loss while the coated sample had a 5.34 ±0.58% reduction in protein content from the initial level. A significant ($p < 0.05$) difference in % change in nutrients was observed between the uncoated and coated tomato sample for fiber (11.4 ±2.01 and 3.20 ±0.74%), ash (2.86 ±0.23 and 0.00%), carbohydrate (62.77 ±4.76, 26.55 ±2.07%), vitamin C (7.46 ±0.88 and 0.06 ±0.00%) and beta-carotene (7.98 ±0.85 and 0.80 ±0.01%), respectively. Meanwhile, there was no significant difference in the % change of crude fat content between coated (8.45 ±1.97 and 10.08 ±0.51%) and uncoated tomato sample (Table 3).

The vitamin C and beta-carotene contents of coated and uncoated tomato fruits (Table 4) showed no significant ($p > 0.05$) difference across the storage period. Although, the uncoated fruit showed a significant decrease in the levels of vitamin C (19.03 ±1.03 to 17.61 ±1.03 mg/100 g) and beta-carotene (469.63 ±4.15 to 432.17 ±5.60) from the initial and final storage times. The percentage change in vitamin C and beta-carotene contents as presented in Figure 7 showed significant difference between uncoated and coated tomato fruit.

The significant weight loss observed in uncoated fruit samples is consistent with reports on strawberry and pomegranate by Ghasemnezhad et al. (2013) and banana by Hossain and Iqbal (2016). The impacts of coating as a semi-permeable barrier against moisture likely contributed to the reduction in weight loss in the coated fruits (Kocira et al., 2021). As a result of respiration activities and moisture transfer, weight loss is common during the storage of fruits. Fruit moisture supplies part of the medium for enzymes and general metabolic processes to work normally (Ekpete et al., 2013). The fact that tomatoes lose significantly more

**Table 3.** Nutrient composition of coated and uncoated tomato fruit

| Parameters, % | Time, days | | | | |
|---|---|---|---|---|---|
| | 0 | 3 | 6 | 9 | 12 |
| | | | Uncoated | | |
| Moisture | 87.82 ±0.03$^{a}$ | 91.13 ±0.07$^{b}$ | 91.83 ±0.01$^{c}$ | 93.18 ±0.02$^{d}$ | 94.04 ±0.25$^{e}$ |
| Protein | 2.02 ±0.03$^{d}$ | 2.00 ±0.01$^{d}$ | 1.83 ±0.22$^{c}$ | 1.70 ±0.05$^{b}$ | 1.52 ±0.02$^{a}$ |
| Fibre | 1.14 ±0.01$^{b}$ | 1.10 ±0.00$^{b}$ | 1.09 ±0.00$^{b}$ | 1.02 ±0.00$^{a}$ | 1.01 ±0.01$^{a}$ |
| Crude fat | 0.74 ±0.02$^{e}$ | 0.69 ±0.00$^{d}$ | 0.61 ±0.04$^{bc}$ | 0.55 ±0.00$^{b}$ | 0.51 ±0.02$^{a}$ |
| Ash | 0.35 ±0.01$^{a}$ | 0.33 ±0.00$^{a}$ | 0.35 ±0.01$^{a}$ | 0.36 ±0.02$^{a}$ | 0.34 ±0.01$^{a}$ |
| Carbohydrate | 7.93 ±0.07$^{e}$ | 4.75 ±0.03$^{d}$ | 4.27 ±0.27$^{c}$ | 3.19 ±0.13$^{b}$ | 2.58 ±0.05$^{a}$ |
| | | | Coated | | |
| Moisture | 88.07 ±0.25$^{ab}$ | 88.85 ±0.65$^{ab}$ | 89.52 ±0.32$^{b}$ | 90.06 ±0.38$^{b}$ | 90.32 ±0.61$^{b}$ |
| Protein | 1.87 ±0.03$^{b}$ | 1.88+0.01$^{b}$ | 1.84 ±0.01$^{b}$ | 1.82 ±0.03$^{b}$ | 1.77 ±0.01$^{a}$ |
| Fibre | 1.25 ±0.08$^{a}$ | 1.24 ±0.02$^{a}$ | 1.23 ±0.01$^{a}$ | 1.23 ±0.03$^{a}$ | 1.21 ±0.06$^{a}$ |
| Crude fat | 0.71 ±0.01$^{a}$ | 0.68 ±0.00$^{a}$ | 0.65 ±0.00$^{a}$ | 0.66 ±0.02$^{a}$ | 0.65 ±0.03$^{a}$ |
| Ash | 0.38 ±0.07$^{a}$ | 0.38 ±0.04$^{a}$ | 0.37 ±0.03$^{a}$ | 0.34 ±0.01$^{a}$ | 0.38 ±0.07$^{a}$ |
| Carbohydrate | 7.72 ±0.15$^{e}$ | 6.97 ±0.15$^{d}$ | 6.39 ±0.31$^{c}$ | 5.89 ±0.63$^{a}$ | 5.67 ±0.72$^{a}$ |

Values are represented as mean ±SEM of triplicate determinations.
Value with different alphabets along a row are significantly ($p < 0.05$) different.

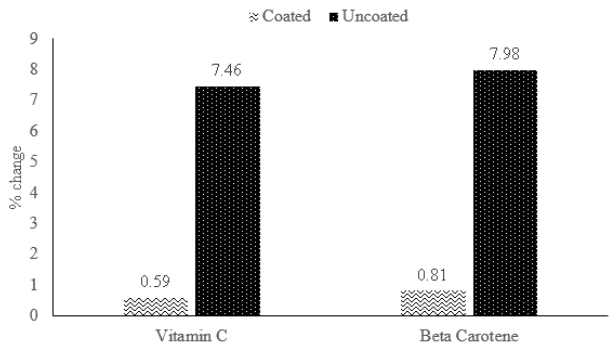


**Fig. 7.** Change in vitamin C and beta-carotene contents of coated and uncoated tomato fruit

moisture and weight than eggplant might be related to the fibrous nature and thick skin of eggplant, which makes it less accessible to pathogens and so extends its shelf life (Agoreyo et al., 2012). The chitosan-starch film developed in this present study did not only retain the moisture content but also the freshness of the fruits. This is due to the fact that when moisture is lost from fruits, they shrivel and become dry, lowering their acceptability and market value.

The significant reduction in the loss of moisture content in coated garden egg fruit compared to the uncoated garden egg fruit agrees with the report of Toliba et al. (2014), who found that employing chitosan and carnauba composite coatings reduced loss of moisture while increasing the shelf-life. Moisture loss may be caused by external variables such as temperature and humidity (Yahaya and Mardiyya, 2019), as well as physiological factors such as shape, surface structure and skin permeability (Bovi et al., 2016). Fruits lose a lot of moisture through transpiration because of their structure. Stomata, which are natural apertures in fruits and leafy vegetables and lenticels, which allow gas and water to escape to the atmosphere, are found on some fruits and leafy vegetables (Kritzinger, 2019). Unlike eggplant, tomato fruit lacks stomata and

**Table 4.** Vitamin C and β-carotene contents of coated and uncoated tomato fruit

| Parameters | Time, days | | | | |
|---|---|---|---|---|---|
| | 0 | 3 | 6 | 9 | 12 |
| | Uncoated | | | | |
| Vitamin C | 19.03 ±1.03$^{c}$ | 18.73 ±0.03$^{b}$ | 18.58 ±0.14$^{ab}$ | 18.23 ±0.20$^{a}$ | 17.61 ±1.03$^{a}$ |
| β-Carotene | 469.63 ±4.15$^{d}$ | 463.77 ±3.82$^{d}$ | 456.10 ±4.88$^{c}$ | 441.82 ±6.08$^{ab}$ | 432.17 ±5.6$^{a}$ |
| | Coated | | | | |
| Vitamin C | 18.66 ±1.74$^{a}$ | 17.96 ±1.74$^{a}$ | 18.61 ±0.96$^{a}$ | 18.57 ±0.42$^{a}$ | 18.55 ±0.12$^{a}$ |
| β-Carotene | 494.08 ±13.55$^{a}$ | 490.08 ±10.05$^{a}$ | 483.87 ±5.70$^{a}$ | 487.77 ±6.06$^{a}$ | 490.08 ±7.01$^{a}$ |

Values are represented as mean ±SEM of triplicate determinations.
Value with different alphabets along a row are significantly ($p < 0.05$) different.

lenticels, therefore the majority of water vapor and other gases pass through the stem scar. This might be why, in certain parts of southern Africa, it has long been customary to store tomato fruit upside down, ostensibly to decrease water loss from the stem scar. However, commercial procedures involve waxing tomato fruit. The higher moisture content observed in tomato fruit than was observed in eggplant might be due to the fibrous nature of garden egg. Although the moisture content in tomato fruits increased, it was significantly lower in coated fruit. This may be attributed to the formation of a semipermeable environment by the chitosan-cassava starch coat which reduces the rate of metabolic activities within the fruit system (Shehata et al., 2021). The metabolic activities may include the breakdown of carbohydrate molecules to $CO_2$ and $H_2O$, thereby increasing the moisture content.

Despite the fact that protein only makes up around 1% of the total mass of fresh vegetable and fruit tissues, it is an important component. The loss of nutrients over time in eggplant and tomato, regardless of whether or not they were coated, suggests that nutrients are lost due to a range of internal and extrinsic reasons. It's possible that the large drop in protein concentration in uncoated fruits (eggplant and tomato) is related to protein solubility in water, making them less accessible in the tissues of the fruits. The significantly lower change in the concentration of protein in the coated fruits might be due to the water barrier effect of the chitosan-cassava starch coat.

Proteins are made up of amino acids, which are the building components; however, due to the impact of heat, they become inaccessible after a period of storage. Another explanation for the drop in protein concentration might be due to higher storage temperatures, which could allow specific amino acids (for example, lysine) to become chemically linked to simple sugar, creating brown colors and rendering them inaccessible through the Millard reaction (Dandago, 2009). By controlling the entry and outflow of gases and water, films can vary the interior environment between the fruit and the external environment. This might also help regulate the temperature and relative humidity of the fruits' surroundings. Several activities (such as enzyme activities) that may lead to protein breakdown are reduced. The importance of protein in human diets cannot be overstated, since it is required for human growth, maintenance and development. It also plays a role in the synthesis of blood cells, as well as nucleic acid, coenzymes, hormones, immunological response, cellular repair and other life-sustaining substances (Morris and Mohiuddin, 2020). According to most investigations, chitosan and chitosan composite coats/films have negligible influence on the proximate compositions of fruits and vegetables. Despite the low protein content of the uncoated fruits, the current investigation found that protein was retained in the coated fruits. As a result, the developed coat may be used to improve protein retention and availability in other foods with higher protein concentration.

Lipids are primarily found as triglycerides or phospholipids, and they supply energy to plants during germination by forming components of cellular membranes and cuticle waxes (esters of glycerol and fatty acids). Except for avocados, olives and many seeds, most postharvest goods are rather low in total lipids. Fruit and vegetable fat content is typically less than 1% and varies depending on the product. Exposure to air may have resulted in a large loss of lipid content in the uncoated fruit under consideration. Oxidation and hydrolytic rancidity, both of which generate inappropriate tastes, can result from an uncontrolled oxygen influx in fruits. The use of coating materials with good barrier characteristics reduces the loss of this nutrient. Fat in food and food items improves the flavor and taste because fats dissolve and concentrate taste and molecules with flavor. As such, chitosan-starch coat might be used to keep and improve the flavor of fruit during storage.

The decrease in the amount of carbohydrate present in uncoated fruits as reported in this work is consistent with the findings of Idah et al. (2010), who investigated the effects of storage duration on several nutritional features of orange and tomato. The scientists found that the carbohydrate content of the fruits they investigated had decreased. The ability of coatings to slow fruit ripening might explain the substantial ($p < 0.05$) difference in the change (%) in carbohydrate content seen in coated fruits in the present study. Hydrolysis of polysaccharide rises with fruit ripening, resulting in increased production of soluble sugar, which is required by plant cells for respiration (Idah et al., 2010). Carbohydrates are essential for the storage of energy reserves and the formation of the cell's structure (Wakim and Grewal, 2021). Simple carbohydrates, which are also photosynthesis's direct products, are crucial parts of the attributes of sensory qualities. Chitosan and chitosan composite coatings offer a modified and regulated environment for food products by regulating carbon dioxide and oxygen entry and outflow. When oxygen levels are low, the respiratory activity of plants (fruits) drops, enabling polyphenol-oxidase, ascorbate-oxidase and glycolic-oxidase oxidation activities to be reduced, all of which are involved in fruit ripening (Caleb et al., 2013; Meitha et al., 2020). In the presence of decreased oxygen levels, genes of enzymes involved in fruit development and ripening may be repressed (Itai et al., 2015; Fabi and Do Prado, 2019). Energy which may be obtained from carbohydrate drives this process.

Dietary fiber is defined as non-digestible carbohydrates and lignin found naturally in plants (Stephen et al., 2017). The modulation function of the digestive tract is one of the most important functions of dietary fiber (Jha and Mishra, 2021). Meals high in fiber induce fullness early and are often low in calories when compared to meals heavy in other food categories (Chambers et al., 2015). The fact that fruit fibers are mostly composed in their tissues (for instance pectin) may explain the substantial ($p < 0.05$) difference in fiber content between coated and uncoated fruit. Pectins, on the other hand, are galacturonic acid-rich polymers, such as homogalacturonan, a homopolymer of -1, 4-linked galacturonic acid residues with varying degrees of methyl esterification at the $C_6$ position (Phyo et al., 2017). However, when the degree of esterification increases during ripening, the fruit's pectin (fiber) concentration drops. In other words, because coated fruits may take longer to ripen, their fiber content will be higher than uncoated fruits.

Vitamin C is a very unstable nutrient. Therefore, it is frequently used in estimating the total nutrient retention in food products (particularly fruits and vegetables) (Varzakas and Tzia, 2014). During storage, vitamin C is very susceptible to oxidation and leaching into a water-soluble medium (Giannakourou and Taoukis, 2021). Ascorbic acid and its first oxidation product, dehydroascorbic acid, make up vitamin C (which can be decreased in the human body). The significant decrease of vitamin C levels in uncoated fruits found in this study echoed the findings of Ullah et al. (2017), who looked at the impact of edible coatings on the biochemical fruit quality and storage life of bell pepper. The barrier feature of coatings may be responsible for the reduction in ascorbic acid loss in coated fruits as they produce a modified environment for the stored fruits, lowering the rate of plant respiration and metabolism (Ullah et al., 2017). Vitamin C is present in fruits and vegetables and is needed by the body for a number of biological functions such as collagen production, wound healing, and cartilage, bone and tooth repair and preservation. Vitamin C is an antioxidant, which means it can neutralize free radicals, which can destroy biological cells genetically (Pehlivan, 2017). Chitosan-starch coating may be used on a large scale

to preserve fruits high in vitamin C content while also making this vitamin available.

Carotenoids are pigments that exist naturally and are responsible for the color shades and nutritional value of plant materials in the form of dietary antioxidants. They are crucial bioactive compounds that are converted into vitamin A. Ibrahim et al. (2019) detected an increase in beta-carotene levels throughout field ripening and found that both coated and untreated tomato fruits had higher carotenoid concentrations. After 30 days of storage at 35°C, Saci et al. (2015) discovered a significant decline in carotenoid content in carrot and mango drinks. Fruit ripening is responsible for the rise in carotenoid concentration. However, the significant change in beta-carotene content seen in coated tomato fruit in this study might be attributed to the coat's barrier function (water and gas transfer characteristic), which slows fruit ripening. As a consequence, the chitosan-starch coating retained vitamin A in coated fruits more than untreated fruit samples, suggesting that it might be adopted on a large scale basis. This might help to alleviate the scarcity of fruit, which is the primary source of this vitamin, particularly for children. The most frequent dietary insufficiency is vitamin A deficiency, which leads to blindness (Hodge and Taylor, 2021).

## CONCLUSION

The use of chitosan starch coating on tomato and garden egg fruits revealed that coating has a potential impact on reducing the physiological weight loss of the fruits (tomato and eggplant) during storage. It was also shown that coated fruits retained the nutrient contents of the fruits considerably ($p < 0.05$). However, the storage time was not considerably long, especially for tomato fruit. Therefore, further study should be done in order to optimize the coat formulation, as well as the blending. With further research and improvement on the shelf-life period, fruits and vegetables, especially in Nigeria, may be available and in circulation even after their peak seasons.

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