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GUM ARABIC AND BEESWAX AS EDIBLE COATINGS FOR EXTENDING THE POSTHARVEST SHELF LIFE OF TOMATO (*LYCOPERSICON ESCULENTUM* L) FRUIT

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ABSTRACT

Edible coatings can provide an alternative for extending the postharvest shelf life of fresh fruits and vegetables. The effect of two edible coatings and their combinations were studied on some physical qualities of tomato fruits. Gum arabic was formulated from the exudate of *Acacia* tree, and beeswax was sourced from the Horticulture Department, University for Development Studies. Cassava starch was used as a plasticizer for both materials. Tomato fruits were treated with gum arabic, beeswax, and a combination of the two at concentrations 5, 10, and 15%. Treated and untreated fruits were examined for their weight loss and decay during 20 days of storage and sampling were done at 4 days intervals. Fruits coated with gum arabic alone did not show much positive impact on weight loss and decay when compared to the control fruits. The beeswax alone however showed a positive impact on weight loss and decay. Furthermore, the combination of the beeswax and gum arabic resulted in the highest performance with reduced weight loss of 26.7%, and 13.9% decay after 20 days in storage. Hence, the combination of gum arabic and beeswax could extend the postharvest shelf life of tomato fruits at 29˚C and 72 - 75% temperature and relative humidity, respectively.

Keywords: Beeswax, gum arabic, tomato fruit, edible coating, postharvest shelf life**.**

Introduction

Tomato (*Solanum lycopersicum* L.*)* is considered a valuable fruit due to its organoleptic and nutritional properties including bioactive compounds, antioxidant, and anticarcinogen activities (Narváez-Ortiz *et al*., 2018; Casals *et al*., 2019). However, harvested tomato fruits are metabolically active, leading to ripening and spoilage that must be controlled to perpetuate postharvest quality. Tomato fruit has a very short postharvest life as it contains 80-90% of its weight as water and if left without its cuticle, the water then quickly begins to evaporate, resulting in great losses (Vipan *et al*., 2018). The quality of tomato fruits after harvest continuously alters due to the rapid rates of respiration and transpiration, fruit decay, and active metabolic processes (Pedreschi., 2017), of which respiration is the main factor associated with tomato postharvest shelf life in the tropical regions. Respiration leads to faster ripening and deterioration of fruit quality (Dos Santos *et al*., 2019).

There are various postharvest management practices of fruits and vegetables such as harvesting, handling, packing, storage, and transportation (El-Ramady *et al*., 2015; Ayomide *et al*., 2019). Among these practices, storage of easily perishable fruits, in particular tomato which is a climacteric fruit (has been a challenge). Storage at freezing or low temperatures and chemical treatments are some of the main conventional methods for prolong shelf life of tomato (Ayomide *et al*., 2019). However, temperature controlled storage facilities are expensive especially for farmers in Africa, and the use of chemicals poses several environmental and health challenges (Alenazi *et al*., 2020). Therefore, an economical and bio-based alternative is necessary for both prolonging the shelf life with less or no toxicity and keeping the production costs at a minimal. Hence the prospect of using edible coatings such as gum arabic and beeswax. The utilization of both physical methods (ozone, electrolyzed water and controlled atmospheric packaging) and natural composites (chitosan, essential oils, biocontrol agent, antifungal edible coatings and organic acids) serve as possible alternatives, and safe ways of preserving fresh produce (Droby *et al*., 2016; Usall *et al*., 2016; Tzortzakis & Chrysargyris., 2017; Romanazzi *et al*., 2018). The application of edible coatings from natural sources on perishable fresh produce is considered cheaper, safer and efficient for extending the postharvest shelf life and improving food appearance (López-Palestina *et al.*, 2018; Yadav *et al.*, 2022).

Edible coatings are thin layers of edible natural materials made of proteins, lipids or polysaccharides that are applied to the surface of products to protect and serve as a barrier to moisture, oxygen, carbon dioxide, and solute movement, hence minimizing respiration, water loss and oxidation reaction rates (Hassan *et al*., 2018; Yadav *et al*., 2022). Among the natural compounds, beeswax and gum arabic are suitable postharvest applications for an edible coating for fresh commodities. Gum arabic, also known as gum acacia, is a dried gum exudate obtained from stems or branches of *Acacia* species. Owing to its unique emulsification, and film-forming, gum arabic has been used in pharmaceutical and food industries as stabilizers and as an edible coating to extend the postharvest quality of tomato (Ali *et al*., 2010), banana (Magbool *et al*., 2011), strawberry (Tahir *et al*., 2018), sweet cherry (Mahfoudhi & Hamdi., 2015), green chillies (Valiathan & Athmaselvi, 2018), cucumber (Al-Juhaimi *et al*., 2012), persimmon fruits (Saleem *et al*., 2020), Mango (Khaliq *et al*., 2015; Khaliq *et al*., 2016) and many others. Beeswax on the other hand is a natural lipid-based coating with a complex mixture of hydrocarbons, free fatty acids, diesters and exogenous substances having a very low affinity for water (Fratini *et al*., 2016; Gunaydin *et al*., 2017). This coating has been applied to fruits and vegetables (Salehi *et al*., 2020).

In some sub-Saharan African countries such as Ghana where storage and transport facilities are not sufficient and not available in rural communities, postharvest losses of fruits and vegetables continue to be a major challenge. Any degree of postharvest loss of tomatoes has consequences for farmers, traders and even consumers (Abera *et al*., 2020). Reduction in postharvest loss would be of great significance to growers and consumers especially those in the rural areas. Use of coatings is gathering attention due to safety consideration of infections (Ghosh & Singh., 2022).

Hence, the study aimed to prolong the postharvest shelf life of tomatoes using gum arabic and beeswax as coating materials while maintaining the physical properties of the fruits under spontaneous conditions.

Experimental

Plant material

The plant material used for the entire experiment is tomato (*Solanum lycopersicum* L.) fruits. Freshly harvested tomato fruits (30% to 50% of the surface being pink to red according to the United States Department of Agriculture USDA class 4 color) from the 'Popvriend' variety were obtained from a local farm in Naabogu, Tamale, Northern region of Ghana. After harvesting, the tomatoes were sent to the Spanish Laboratory Complex (Food Technology Laboratory), University for Development Studies (UDS), Nyankpala campus. Fruits were selected for uniform size and shape, free from mechanical injury and pathogenic infection.

Preparation of gum arabic and beeswax

The gum arabic was extracted by wounding the back of selected *Acacia* trees with a machete and collecting the whitish liquid exudates (gum) into a container and then dried for 24h at 35°C to obtain a dry exudate of the sap. The dried gum was ground into powdered form with a mortar and pestle. An electronic balance (Sartorius, CP 124S, USA) was used to weigh 5g, 10g and 15g of the gum powder and each dissolved in 100ml distilled water. To improve the strength and flexibility of the coating, cassava starch was added to serve as a plasticizer by adding 1g of the starch powder to the solution. The solution was heated on a heating mantle at 60℃ for 15min and then filtered with a perforated sieve to remove any undissolved substances and then allowed to cool for 5min (Hu *et al*., 2019). The treatments were selected according to preliminary experiments for tomatoes to assure adherence and steadiness of the coating.

The Beeswax was obtained from the Department of Horticulture, UDS. Beeswax weighing 5g, 10g and 15g was each dissolved in 100ml of distilled water in addition to 1g of cassava starch powder which was added to improve the flexibility and strength of the beeswax. The content was heated for 15min at 60℃ and brought to cool for 5min at room temperature (Tedeschi, *et al*., 2018). A mixture of gum arabic and beeswax was also prepared by weighing 2.5g, 5g and 7.5g of each with an addition of 1g cassava starch powder in 100 ml distilled water. The combined solution was heated for 15min at 60℃ and the solution was allowed to cool for 5min at room temperature.

Coating of tomato fruits

The tomato fruits were washed with running tap water and dipped in 0.05% sodium hypochlorite solution for 3min prior to the coating as described by Ali *et al*., (2010) to disinfect the fruits from any fungal infection that was not visible. The fruits were rinsed and air-dried on a paper towel before coating. The tomato fruits were randomized, and 70 fruits were selected, of which 7 fruits were immersed in each concentration of the edible coatings (gum arabic, beeswax, and mixture of the two) at 5%, 10% and 15%, and 9 fruits in distilled water as a control for 2-3 min. Each treatment was conducted with three replicates, and air-dried, packed in cardboard boxes and stored at room temperature (29˚C) and relative humidity (72-75%). The data were collected before treatment (day 0) and at 4-day intervals for 20 days.

Weight loss determination

The tomato fruit weight loss was determined as described by Khaliq *et al.* (2015). Before storage, all fruits were weighed using an electronic balance (Sartorius, CP 124S, USA). The fruits were weighed at a four-day interval and the results were expressed as:

Percentage weight =

$$\frac{\text{Weight of fresh fruit (g)} - \text{Weight after interval (g)}}{\text{Weight of fresh fruit (g)}} \times 100$$

Decay percentage

The decay of the treated and untreated fruits was determined by visual observation by viewing the development of spots, softening, and rotting on the surface of the fruit. The decay percentage was calculated as described (El-Anany *et al*., 2009):

Decay percentage =

$$\frac{\text{Number of fruit}}{\text{Initial number of fruits}} \times 100$$

Data analysis

The experiment was conducted in a completely randomized design (CRD). The experiment was repeated thrice with 7 fruits in each treatment and the data were analyzed by ANOVA using the SigmaPlot 14.0 software package (SigmaPlot, Germany) at a 5% level of significance.

Results and discussion

Postharvest loss of tomatoes is a huge problem in developing countries, especially in the Northern region of Ghana. This leads to economic losses for the farmers, market women and finally the consumer. The study evaluated beeswax and gum arabic as cheap and simple coating method that farmers and consumers can adopt to extend the shelf life of tomato fruits.

Effect of beeswax on tomato fruit weight

Both coated and uncoated fruits started to lose weight from day 4. However, the weight loss of the control (uncoated fruits) increased significantly ($P<0.05$) resulting in the highest weight loss (72.5%) on day 20 of storage. It was observed that weight loss decreased with an increasing coating percentage of beeswax, of which 15% of beeswax had the less weight loss of 32.5% after day 20 (Fig 1). Tomato fruits are inherently covered by a wax layer which forms an efficient barrier against unregulated water loss across the cuticle. The formation of an additional layer over the natural wax provided by coatings containing hydrophobic compounds improves the high water resistance of the fruit (Bayer, 2020). The decreased weight loss in the beeswax coated tomato compared to uncoated ones might be due to the effectiveness of this coating as a moisture barrier. Fagundes *et al*. (2015) formulated hydroxypropyl methylcellulose-beeswax edible coatings to maintain the postharvest quality of cold-stored cherry tomatoes. They observed a significant increase in weight loss of various formulations of coated fruits compared to the uncoated and conclude that some formulations partially remove the natural waxes on the surface of the fruit and negatively affect the weight. From our study, the addition of cassava starch may have enhanced the plasticity and flexibility and reduced brittleness.

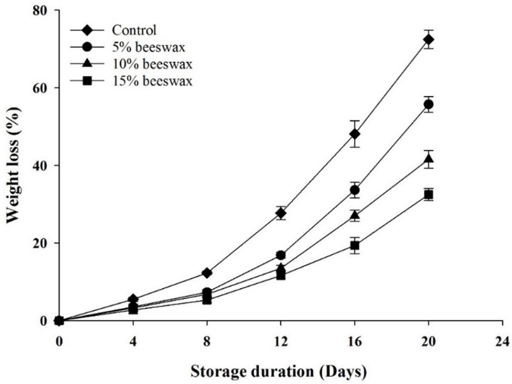

Fig. 1: Weight loss of tomato fruits coated with 5%, 10%, 15% beeswax using 1% cassava starch as plasticizer.

Effect of gum arabic on tomato fruit weight At the initial storage time, 15% of gum arabic coated fruits showed less weight loss, but as storage progressed, an increase in weight loss (75%) compared to the uncoated fruits occured. However, 5 and 10% gum arabic showed a significant decrease in weight loss at 20 days, with 5% gum arabic showing a minimum weight loss of 52.2% (Fig 2). This may be an indication that the formulation of gum arabic with cassava starch is effective at 5% compared to the 10% and 15%. Ali *et al*., (2010) reported 10% and 15% gum arabic supplemented with glycerol monostearate (1.0%) as a plasticizer to be effective in weight loss reduction. They further reported a higher weight loss in 20% gum arabic coating on tomato fruits. According to literature, edible coating application is known to significantly or not significantly affect the weight loss of fruits depending on the innate features of both the coating and the fruit. Thus, for example, the work of Ruiz-Martínez *et al*. (2020) and Zekrehiwot *et al*. (2017) showed less reduction in weight loss and visual appearance when tomatoes were coated with *Flourensia cernua* extract and pectin, respectively. Moreover, the application of guar gum containing ginseng extract on sweet cherry expand its shelf life by controlling water loss and delay of firmness (Dong, & Wang 2018), and basil seed gum on fresh cut apricots decreased water vapour permeability (Hashemi *et al*., 2017).

In the present study, the higher weight loss in 15% gum arabic compared to 5, and 10% and the control could be explained by the thickness of the coating, whereby the 15% gum arabic completely covered the surface of the fruit. It was observed that the plasticizer used was not effective for 15% gum arabic as it became brittle on the surface of the tomato fruit as it dried.

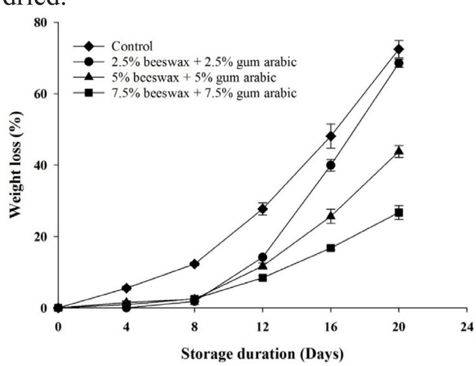

Fig. 2: Weight loss of tomato fruits coated with 5%, 10%, 15% gum arabic using 1% cassava starch as plasticizer.

Effect of combination of gum arabic and beeswax on tomato fruit weight

Equal proportions of gum arabic and beeswax were combined at different concentrations to determine their effect on fruit weight loss. The coated fruits maintained their weight from the first day of storage to day 8 with no significant difference ($P<0.05$) among the various concentrations (Fig 3). After day 8, variations were observed whereby 15%

combined coating resulted in the lowest weight loss of 26.7%, followed by 10% and 5% combined coating at the end of the storage. This might be due to edible coatings being able to cover the fruit surface and thereby reducing respiration and transpiration and subsequently reducing the weight loss of the fruit. In similar studies, Gunaydin *et al*., (2017) and Fagundes *et al*., (2014) reported the combination of hydroxypropyl methylcellulose (HPMC) and beeswax (BW) composite with food additive to be most effective in controlling the weight loss of plums (*Prunus salicina*) and cherry tomatoes, respectively. The effectiveness of beeswax coatings and its combination in reducing the weight loss of fruits could also be because of the hydrophobic nature of beeswax than the gum arabic coatings which acted as a barrier for water and other solute molecules between the outer and inner environment of the fruits. Eshetu *et al*., (2019) reported a similar result with two varieties of mango coated with a mixture of beeswax and chitosan.

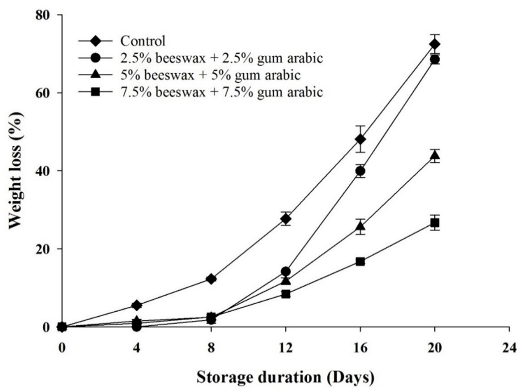

Fig. 3: Weight loss of tomato fruits coated with 5%, 10%, 15% combination of beeswax and gum arabic using 1% cassava starch as plasticizer.

Effect of beeswax coating on tomato fruit decay

Fruits coated with 15% beeswax recorded the least decay followed by 10% and 5% with the control showing the highest decay percentage (Fig 4). Few symptoms of decay occured after day 4 of storage for control and 5% beeswax coated fruits. For 10% and 15% beeswax, decay begun on the 8th and 12th day, after which the decay began to spread throughout the fruits. The highest decay percentage was recorded in the uncoated fruits (71.1%) after the last day of storage. Among the coated fruits, 5% beeswax had the highest decay (63.2%) and 15% beeswax resulted in the lowest decay of 33.9%. The effectiveness of beeswax may be due to the film-forming property, which acted as a fence and thus reduced microbial activity and acted as a barrier against carbon dioxide and oxygen thereby delaying senescence (Jawaid and Swain, 2018; Tiwari *et al*., 2022; Yadav *et al*., 2022). A similar observation was reported by Zewdie *et al*., (2022) whereby tomatoes dipped in neem leaf extract then coated with beeswax improved the postharvest shelf life and quality of treated fruits compared to untreated fruits.

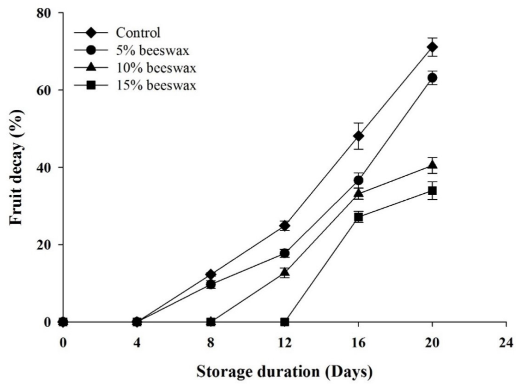

Fig. 4: Effect of beeswax coating on tomato fruit decay during storage. Fruits were coated with 5%, 10%, and 15% beeswax using 1% cassava starch as plasticizer.

Effect of gum arabic coating on tomato fruit decay

Percentage decay of fruits coated with gum arabic was relatively higher than the control fruits. However, the percentage decay of gum arabic was not consistent as compared to the other treatments (Fig 5). There was no visible sign of decay on the 5% gum arabic coated and controlled fruit until day 8 of the storage period. However, 10% and 15% gum arabic showed symptoms of decay on day 4, with 15% gum arabic resulting in the highest decay of 74.5% which was slightly above the control. This could probably be because the cassava starch could not serve as the right plasticizer thereby causing the gum arabic coatings to become brittle and hence causing bruising on the surface of most of the gum coated fruits thus increasing the surface layer for evaporation and contact for microbial infection. Although the percentage of deterioration was low in the first 4 days, it increased rapidly in the subsequent days of storage. The main cause of fruit deterioration is fruit ripening due to ethylene production. High temperature fastens the rate of fruit ripening (Siddiqui *et al*., 2018), and the storage temperature of the tomato fruits may affect the effectiveness of the gum arabic treatments.

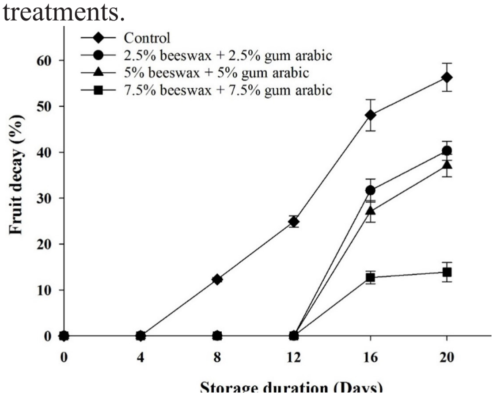

Fig. 5**:** Effect of gum arabic coating on tomato fruit decay during storage. Fruits were coated with 5%, 10%, and 15% gum arabic using 1% cassava starch as plasticizer.

Effect of beeswax and gum arabic combination on tomato fruit decay

The combined coatings (beeswax and gum arabic) significantly ($P<0.05$) inhibited fruit decay more than the control. The control recorded a higher value of decay incidence of 71.1%. However, decay incidence of treated tomatoes with 15% combined coating was recorded as the lowest, followed by 10% and 5% (Fig 6). A similar observation was reported by Tanada-Palmu & Grosso (2005), who noted that bilayer coating of wheat gluten and lipids (beeswax, stearic and palmitic acids) significantly extend the shelf life of strawberries and delayed senescence for up to 16 days when stored at 7-10°C, and controlled decay. From the present work, symptoms of decay began on day 16 for 15% combined coating, and at the end of storage duration, about 13.9% decay was recorded. This suggests that the combined coating was more effective for controlling decay than the single coating material. Amin *et al*., (2021) reported that the combination of chitosan–*Aloe vera* coatings emulsified with beeswax reduced disease incidence in mango fruits, thereby increasing the shelf life and marketable period of mangoes. A combination of coconut oil and beeswax coating on postharvest storage quality of lemon at ambient storage demonstrated increased shelf life of lemon with quality such as weight loss, respiration rate, and decay incidence (Nasrin *et al*., 2020).

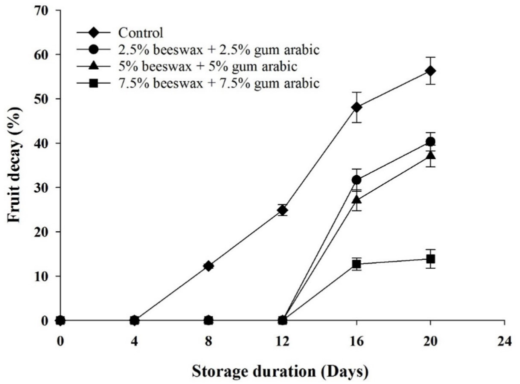

Fig. 6: Effect of combination of beeswax and gum arabic coating on tomato fruit decay during storage. Fruits were coated with 5%, 10%, 15% beeswax and gum arabic using 1% cassava as plasticizer.

Conclusion

Edible coatings are mostly used for the packaging and preservation of food. Beeswax from honeycomb, and gum arabic from *Acacia* tree are natural and edible products that are essential for food storage. Beeswax and gum arabic were used as coatings on tomato fruits in this study. The combination of beeswax and gum arabic effectively delayed softening of tomato fruits as indicated by a reduction of weight loss and decay process. This shows that the combination of beeswax and gum arabic has a valuable impact of maintaining freshness and delaying spoilage in tomato fruits. Further studies to quantify the microbial decay and other physico-chemical parameters should be investigated.

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