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# Influence of shea butter, bee wax and cassava starch coatings on enzyme inactivation, antioxidant properties, phenolic compounds and quality retention of tomato (*Solanum lycopersicum*) fruits

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A R T I C L E I N F O

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Edible coating, shelf-life
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A B S T R A C T

This study explored the effect of different locally produced edible coating material, bee wax (BW), shea butter (SB) and cassava starch (CS) coatings on the physical and chemical properties of tomato fruits stored at 20 °C and relative humidity of 80 – 90% for 20 days. The physiochemical properties and quality retention of coated tomato fruits were assessed for antioxidant properties (ABTS and DPPH), total phenolic content (TPC), enzyme activity (PPO), organoleptic properties, weight loss, firmness, and shelf-life of the fruits. Tomato fruits treated with Bee wax (BW) preserve the antioxidant activity, total phenolic content (TPC), organoleptic properties and resisted enzymes activities compared to the SB and CS. The results also suggest that bee wax (BW) treatment delayed ripening, weight loss, firmness, and extended the storage life of fruits compared to the SB and CS. Taking into consideration of the above physical and chemical properties, BW treatment will be a good postharvest technology for retaining the quality and extending the shelf life of fresh tomato fruits. The current findings will make available more information for selecting edible coatings for tomato storage.

## 1. Introduction

*Solanum Lycopersicum,* a member of the nightshade family is widely consumed as fruit salad, fruit drink, as a condiment of soup, sauces and other dishes. The tomato fruit is also categorized as a vegetable with established health benefits (Osae et al, 2017 ). In Ghana, it constitutes a major vegetable that is consumed by every household as evidenced by the fact that it constitutes an integral part of most Ghanaian dishes (Dzanku, Tsikata, & Ankrah, 2021). The provitamin-A activity of tomato is mainly credited to its beta-carotene and gamma-carotene content. Beta-carotene (lycopene) for instance is known for its free radical scavenging effect, a property that is crucial in normal cell growth and activity (Chrysargyris, Nikou, & Tzortzakis, 2016).

In Ghana, major stakeholders in the production and marketing of tomato are concerned not only about increasing the production volumes of farmers but reducing postharvest losses (Boateng et al, 2017). Kitinoja and Gorny (2013), revealed that handling of fresh tomatoes and other vegetables has a direct impact on the storage lives of same. They indicated that the estimated losses of fresh harvests in the developing countries range from 20 % to 50 %. Much of the postharvest losses incurred by farmers and marketers is the result of either inadequate storage facilities or the total lack of same. Addo et al., (2015), showed that the loss of tomato transported from Bolgatanga, in the Upper East Region of Ghana to the capital, Accra, amounted to 20%. The financial impact of these losses on lives of farmers, traders and consumers cannot be overemphasized (Sheahan and Barrett 2017).

Tomato fruits still live and respire after harvesting, however their quality and appearance change during handling. During storage, various physical and chemical processes occur that result in quality deterioration such as wilting and water loss. These two conditions are temperature- and relative humidity-dependent (Ali, Maqbool, Alderson, & Zahid, 2013). Osae et al, (2017), indicated that the reduction of postharvest losses of perishables is crucial to improving food security in developing countries like Ghana. Storage, packaging, and preservation techniques for perishables are almost non-existent in most developing countries. Due to the huge demand for tomatoes in the urban centers of these countries, a large quantity of same are usually transported from the farming areas to these towns, sometimes over an extended period of time, ultimately leading to product deterioration and

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spoilage. To this end, postharvest loss prevention of becomes paramount (Tadesse, Bakala, Mariam, & Security, 2018).

New technologies such as irradiation, salt application, hot water treatment and edible coating have been applied to extend the postharvest lives of various fresh commodities. The use of edible coatings appears to be a good and viable option. Pérez-Soto et al., (2021), showed mineral oil coating to be effective in preserving the quality of tomato as well as extend the postharvest life of same. Nurul (2012) also demonstrated that coating of freshly-cut pineapple and plantain under storage enhanced their quality characteristics.

Despite the advances made in respect of edible coating of fruits and vegetables, there is still limited data on the use and appropriateness of locally available edible coatings (i.e., from Ghana) to preserve tomato. This work therefore aimed to determine the impact and/or appropriateness of locally available edible coatings, thus, shea butter (SB), bees wax (BW) and cassava starch (CS) on the enzyme inactivation, antioxidant properties, phenolic compounds and quality retention of fresh tomatoes. The outcome of the study therefore could serve as a useful guide in the selection of the most appropriate coating specifically for tomato and possibly other fresh farm produce.

## 2. Materials and methods

### 2.1. Plant material

Fresh tomatoes (*Solanum lycopersicum*) were collected from a local farmer in Begoro, Fanteakwa North District (latitude 6.2259.99 ° N; longitude 0.2259.99 ° E) in the Eastern Region of Ghana. To prevent variation in the experimental materials, the tomato samples were chosen based on the uniformity of their firmness, colour, shape, size and were free from bruises and fungal deterioration.

### 2.2. Sample preparation

Three (3) locally available waxing materials (CS, SB, and BW) were used with the control being the untreated sample. The tomato samples were washed with chlorinated water to remove dirt, spray residues, fungal spores and air dried at room temperature (20 ± 1 °C). The cleaned and air dried fruits were divided into 4 lots each containing 30 fruits. Each treatment was replicated three times.

### 2.3. Wax preparation and application

The wax preparation and application were conducted based on the protocol of Singh et al., (2016). Briefly the tomato fruits were dipped or submerged completely in a bath of melted wax such as BW and SB at a temperature of 45 °C. Upon removal, the BW and SB solidified almost instantaneously. The tomato fruit was ready for packing within a minute after dipping. The CS (1.81 mg/mL) slurry was prepared by mixing 200 g of cassava starch with 1.5 litres of water at 90- 95 °C for 10 min. The solution was then heated up with continuous stirring until the starch was gelatinized. The cooked starch was allowed to cool and the fruits were fully dipped in it completely for 30 seconds. The waxed fruits were allowed to air dry at room temperature (20 ± 1 °C). After the surface drying, all the waxed fruits were arranged according to the experimental layout and stored at same temperature in the laboratory. The bee wax was obtained from a local honey farmers in Jasikan in the Oti Region of Ghana, the cassava starch was obtained from a local farmer at Adawso in the Eastern Region of Ghana and the shea butter was also obtained from local market at Madina in the greater Accra Region of Ghana.

### 2.4. Assessment of storage properties

Data on randomly selected fruits in each experimental unit per replication were recorded at 0, 5, 10, 15, and 20 days of storage based on the following parameters: Sensory assessment, antioxidant activity, firmness, TPC, percentage weight loss (% WL), Shelf Life, and enzyme activity (PPO).

#### 2.5.1. Determination of firmness

The Firmness analysis of treated and untreated (control) tomato fruits was conducted with a texture analyzer (TA-XT plus, Stable Micro System, Surrey, UK) as described by Osae et al., (2019) with minor modification. The pre-test, test and post-test speed were 1.00, 0.50, 5 mm/s respectively. The trigger force was set to 5 g and the probe diameter used was 6 mm. The highest compressive force of the tomato fruits was measured as firmness.

#### 2.5.2. Determination of percentage weight loss

At the start of the experiment, three (3) fruits were chosen, marked and used for the measurement of the % WL. The % WL of the waxed tomato fruits was measured with an electronic balance model SP402 (USA, New Jersey, Ohaus Ltd) and estimated in Eq. (1) below (Oladejo et al., 2017; Osae et al., 2019b).

$$\text{Weight loss (\%)} = \frac{Wo - Wp}{Wo} \times 100 \tag{1}$$

Where, $W_0$ is the weight of fresh fruit (g) and $W_{p\ is}$ the weight after storage interval (g).

#### 2.5.3. Determination of PPO enzyme activity

In the assessment of PPO enzyme activity, previously established protocol of Osae et al., (2019) was employed. The percent RA (residual activity) of PPO was estimated by the equation below:

$$RA\ (\%) = B_t / B_0 \times 100 \tag{3}$$

Where $B_t$ is the enzyme activity of the treated sample and $B_0$ is the enzyme activity of the control sample.

#### 2.5.4. Determination of total phenolic content (TPC)

The total amount of TPC in the coated and uncoated tomato fruits was estimated using the Folin- Ciocalteu procedure (Lawson, Lycett, Ali, & Chin, 2019)

#### 2.5.5. Determination of antioxidant activity

To assess the possible source of antioxidation in the coated and uncoated tomato fruits, the DPPH (1,1-diphenyl-2-picrylhydrazyl) and ABTS (2,2-azino-bis-(3-ethylbenzothiazoline-6-sulfonic acid), methods of determination were employed following the established method of Ali et al., (2013) with slight amendments. All the list of chemicals and reagent used for the determination of TPC and antioxidation have been presented in the supplementary materials.

#### 2.5.6. Determination of shelf life

The established protocol of Pobiega *et al,*. (2020) was followed for the determination of the shelf life. The fruits were stored at room temperature until they started to rot. The number of days taken before rotting was observed on fruit was recorded as the shelf life.

#### 2.5.7. Organoleptic properties

The established protocol of Osae et al., (2020) was employed for the sensory assessment. Ten assessors were selected from the School of Applied Sciences and Technology, Department of Food Science and Postharvest Technology, Cape Coast Technical University, and were tasked to evaluate the visual quality attributes (skin colour, attractiveness, firmness, smell, and overall acceptability) of tomato fruits that had been treated with the different coating material.

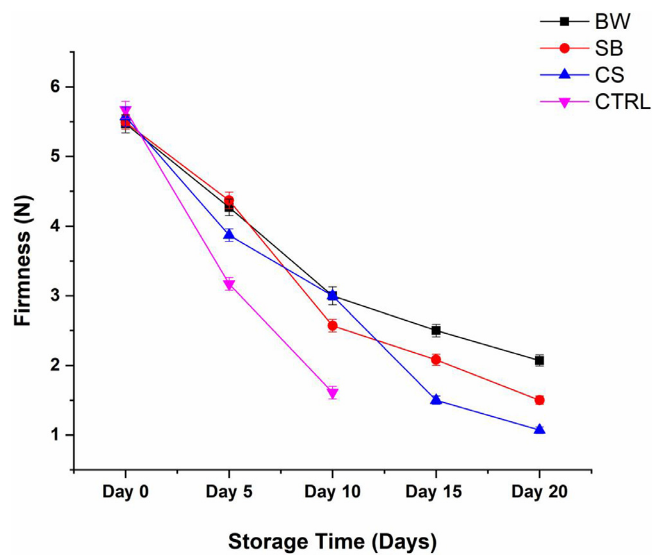


**Fig. 1.** Influence of different edible coating material on firmness of tomato fruits.

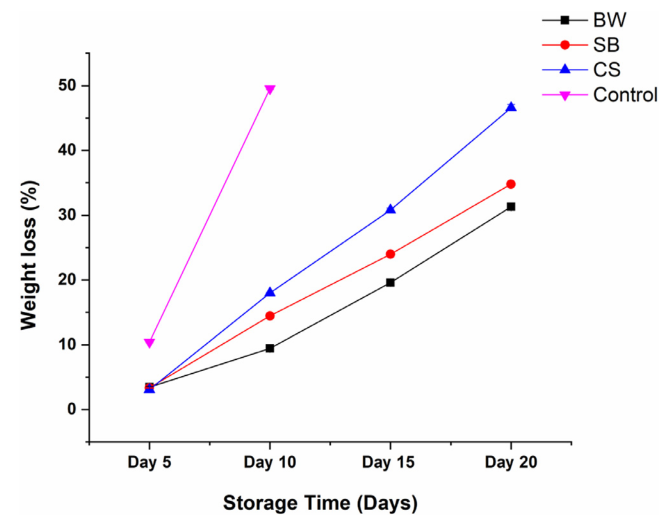


**Fig. 2.** Influence of different edible coating material on percentage weight loss of tomato fruits.

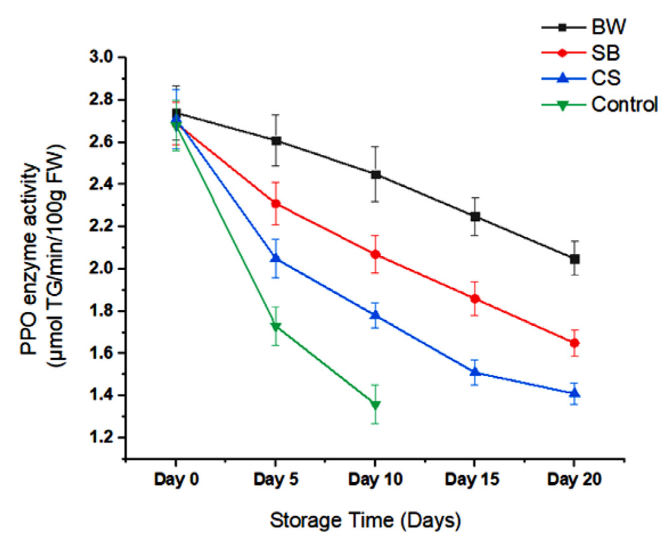


**Fig. 3.** Influence of different edible coating material on PPO enzyme activity to tomato fruits under storage.

## 3. Results and discussion

### 3.1. Effect of different waxing material on firmness

For consumer acceptability and marketability of fruits and vegetables, firmness is considered as one of the most significant indicators. High loss of firmness reduces the quality and market value of the tomato fruit. In the current investigation, loss of firmness happened during storage in both coated and uncoated tomato fruits but it was significantly ($p < 0.05$) higher in the uncoated fruits (Fig. 1). The observed decline in firmness for the uncoated tomato fruits may be due to higher ripening that resulted in rapid softening. According to Mebratie, Woldetsadik, Ayalew, and Haji (2015), the softening of fruits is linked with the solubilization processes of pectic substances which convert carbohydrate (starch) to sugars (soluble) and reduction of moisture from the tomato fruits. In terms of the coated tomato fruits, BW treatment maintained a higher firmness compared to the SB and CS treatments. From day 0 to day 10, the firmness of tomato fruits coated with BW and SB appeared to be at power, but as the storage period advanced, the BW coated tomato fruits preserved higher firmness than those coated with SB and CS. The higher firmness may be ascribed to the water barrier properties of the coating materials particularly the BW, as it serve as physical and a moisture barrier reducing the rate of respiration of the coated tomato fruit. Eshetu, Ibrahim, Forsido, and Kuyu (2019), investigated the impact of BW and other edible coatings treatments on the shelf life and quality retention of mango and revealed that BW and the other edible coating material reduced the rate of respiration and enzyme hydrolysis as well as maintaining the firmness of the mango fruit. Similar observations have been confirmed by other researchers (Galus & Kadzińska, 2015; Joshi & Rao, 2018)

### 3.2. Effect of different waxing material on percentage weight loss

Fig. 2 shows a general significant increase in percentage weight loss (% WL) from day 0 to day 20. It also shows that the uncoated fruits attained higher % WL than the coated fruits. The trend in % WL shows an increase over the storage period and the rapid change for the uncoated fruits compared to the treated samples (BW, SB and CS). The control had a shelf life of ten days which was significantly different ($P < 0.05$) from the coated fruits. On the other hand, the BW coated fruits recorded the lowest % WL compared to those of SB and CS treatment from day 5 to day 20. The lowest % WL attained by the BW coated tomato fruits may be credited to hydrophobic property of BW compared to the other coated materials which served as an obstruction to the movement of moisture and other particles between the inside and outside environment of the coated fruit. Previous investigation of Singh et al., (2016) revealed that edible coating serves as moisture loss barrier creating extremely greater RH around the coated fruits and reduce water migration to the external environment. According to de Jesús Dávila-Aviña et al., (2011), the application of edible coating mineral oil reduced the % WL and preserved the postharvest quality during the storage of tomatoes for 28 days. This assertion was consistent with the study of Tahir et al., (2018), who established that the application of edible coating (gum Arabic) during cold storage of strawberry retarded the % WL and improved fruit quality.

### 3.3. Effect of different waxing material on PPO enzyme activity

One of the enzymes involved in the growth, senescence and development of plants is polyphenol oxidase (PPO). As observed in Fig. 3, the PPO enzyme activity declined gradually in the treated tomato fruits as well as the control during the storage period. The control (untreated) lasted for 10 storage days with maximum decrease in PPO (2.68 – 1.36 µmol TG/min/100 g FW) whereas the minimum decrease in PPO

**Table 1**
Effect of different edible coating on TPC of tomato (**mgGAE/g fw**).

| Edible coatings | Day 0 | Day 5 | Day 10 | Day 15 | Day 20 |
|---|---|---|---|---|---|
| Control | 9.85 ± 0.79$^a$ | 18.65 ± 1.07$^a$ | 11.25 ± 0.17$^d$ | | |
| CS | 9.01 ± 0.22$^a$ | 12.36 ± 0.55$^c$ | 17.68 ± 0.77$^c$ | 23.12 ± 1.67$^c$ | 25.35 ± 0.88$^c$ |
| SB | 9.77 ± 0.37$^a$ | 13.24 ± 0.11$^c$ | 22.36 ± 1.25$^b$ | 28.54 ± 0.55$^b$ | 32.52 ± 1.37$^b$ |
| BW | 9.56 ± 0.77$^a$ | 15.56 ± 0.77$^b$ | 27.11 ± 0.13$^a$ | 32.17 ± 2.17$^a$ | 37.29 ± 1.76$^a$ |

CS: Cassava starch, SB: Shea butter, BW: Bee wax. (Values followed by the different letters (a-d) in the row are significantly different (P <0.05) according to turkey test.

**Table 2**
Effect of different edible coating on ABTS antioxidant activity of tomato **(mgTE/g fw).**

| Edible coatings | Day 0 | Day 5 | Day 10 | Day 15 | Day 20 |
|---|---|---|---|---|---|
| Control | 80.23 ± 0.50$^a$ | 125.21 ± 0.77$^a$ | 95.32 ± 2.23$^d$ | | |
| CS | 80.88 ± 1.57$^a$ | 86.63 ± 2.10$^d$ | 99.57 ± 1.20$^c$ | 120.85 ± 2.56$^c$ | 135.38 ±2.75$^c$ |
| SB | 80.10 ± 2.88$^a$ | 95.06 ±3.12$^c$ | 110.47 ± 3.50$^b$ | 150.78 ± 0.50$^b$ | 165.05 ± 3.05$^b$ |
| BW | 80.97 ± 2.11$^a$ | 120.11 ±1.66$^b$ | 150.22 ± 1.35$^a$ | 170.03 ± 0.50$^a$ | 190.65 ± 0.78$^a$ |

(2.74 – 2.05 μmol TG/min/100 g FW) was attained by the BW treatment (Fig. 3). According to Sarpong et al., (2018), the application of coating gums resisted the activities of the enzymes of apple during 21 days of storage and improved the colour and retained the physicochemical properties. This observation is consistent with the previous works of Singh et al., (2016) and Ghasemnezhad, Zareh, Rassa, and Sajedi (2013), who reported a similar pattern of enzyme activity in eggplant and pomegranate fruit treated with carnauba wax and chitosan coating respectively.

### 3.4. Effect of different waxing material on total phenolic content (TPC)

The TPC of the locally produced waxing material and the control are presented in Table 1. As observed in Table 1, the highest amount of TPC was recorded for the treated tomato fruits which increased gradually from day 0 to day 20. However, the TPC of the untreated (control) tomato fruits lasted for 10 days and increased sharply from day 0 to day 5 but declined from day 5 to day 10 (end of storage). Our results show that there was a significant ($P < 0.05$) difference between the treated and untreated samples. The significant increase of TPC observed from day 0 to day 20 for the treated (waxed) tomato fruits may be linked with the improvement of antioxidant activity (Ali et al, 2013; Yin et al, 2019). This may be attributed to the fact that the coated fruits preserved a greater percentage of antioxidants than the untreated fruits. The fast reduction of TPC of the untreated fruits after day 5 may be ascribed to a higher rate of respiration which led to the reduction or decrease in the TPC due to the degradation of certain phenolic compounds (Ali et al, 2013). Secondly, the decline in TPC for the untreated fruits may be attributed to the breakdown of cell structure and senescence which occurred during the storage period. These results are in agreement with previous studies of Khaliq, Mohamed, Ali, Ding, and Ghazali (2015) and Osae et al., (2019). Singh et al., (2016), established that the application of Carnauba wax coating on eggplant preserved the maximum quantity of the phenolic compounds during storage at room temperature.

### 3.5. Effect of different waxing material on antioxidant activity

The outcome from the antioxidant determinations of the tomato samples treated with different edible coating materials is presented in Tables 2 and 3. High antioxidant activities in terms of DPPH and ABTS were noticed in the treated fruits with BW attaining the highest compared to the other treated samples and the control (untreated). The antioxidant activities of the treated fruit increased consistently from day 0 to day 20 while that for the treated fruits increased rapidly from day 0 to day 5 and declined from day 5 to 10 day (Tables 1 and 2). The increase in antioxidant activity at the early storage period (day 0 – day 5) for the control fruits may be attributed the rapid ripening of fruits due to higher respiration than the treated fruits (Khaliq et al., 2015). It has been reported that the major antioxidant properties in tomatoes are the phenolic compounds, ascorbic acids and carotenoids (Owusu et al., 2015). We found a relationship between the TPC and the antioxidant activities of all the treated samples as well as the control. Our results suggest that increasing TPC directly results in an upsurge of antioxidant activity. Thus, the antioxidant activities of the treated samples are consistent with the results of the TPC. The gradual increase in antioxidant activity of the treated fruits from day 0 to day to day 20 could be ascribed to the delay in ripening compared to the untreated fruits. According to Ali, Maqbool, Ramachandran, and Alderson (2010), tomato fruit coated with gum arabic delayed the ripening process by slowing down the physiological and biochemical changes arising during storage. Conversely, the antioxidant activity of tomatoes also depends on various factors such as production techniques employed, environmental conditions, genetics, pre-harvest techniques and postharvest storage practices (Ali et al., 2013).

### 3.6. Effect of different waxing material on shelf life

The time it takes for fruits to deteriorate after harvest is termed as shelf-life. The application of BW,SB and CS edible coating treatment advanced the storage period of the tomato fruits by 29, 26 and 23 days respectively while the uncoated tomato fruits lasted for a period of 10 days (Fig. 4). The lower shelf-life recorded by the uncoated tomato fruits might possibly be due to maximum rate of respiration which happened during the period of storage. As observed from Fig. 4, the BW (29 days) coated tomato fruits attained the maximum shelf life compared to SB (26 days) and CS (23). This may be related with the other assessed quality parameters as advancement of shelf-life has a direct impact on the preservation of the quality of the fruits. Alternatively, the extended storage life of the BW coated fruits and other treatment (SB and CS) may be ascribed to the fact that the edible coating delayed the rate of respiration and did not encourage the rapid exchange of carbon dioxide and oxygen This outcome is in agreement with the earlier research of Eshetu et al., (2019), who established that the BW treatment of mango increased the shelf-life of the mango to 30 days compared to mangoes treated with chitosan. Yousuf, Qadri, and Srivastava (2018), demonstrated that the shelf-life of banana fruits was extended with the application of edible coating. Saberi et al. (2018), also revealed that use of biocomposite edible coating (guar gum and pea starch) not only improved the quality but also extended the storage life of Valencia oranges.

**Table 3**
Effect of different edible coating on DPPH antioxidant activity of tomato **(mgTE/g Fw).**

| Edible coatings | Day 0 | Day 5 | Day 10 | Day 15 | Day 20 |
|---|---|---|---|---|---|
| Control | 54.34 ± 2.05[a] | 77.33 ± 1.85[a] | 59.23 ± 3.15[d] | | |
| CS | 55.01 ± 1.99[a] | 64.24 ± 1.48[d] | 72.84 ± 1.95[c] | 81.12 ± 2.05[c] | 89.38 ± 3.35[c] |
| SB | 54.48 ± 0.78[a] | 70.4 ± 2.89[c] | 78.66 ± 2.45[b] | 85.92 ± 1.55[b] | 94.18 ± 2.48[b] |
| BW | 55.29 ± 3.01[a] | 73.54 ± 0.98[b] | 84.79 ± 3.44[a] | 92.67±1.05[a] | 101.09 ± 1.77[a] |

CS: Cassava starch, SB: Shea butter, BW: Bee wax. (Values followed by the different letters (a-d) in the row are significantly different (P <0.05) according to turkey test.

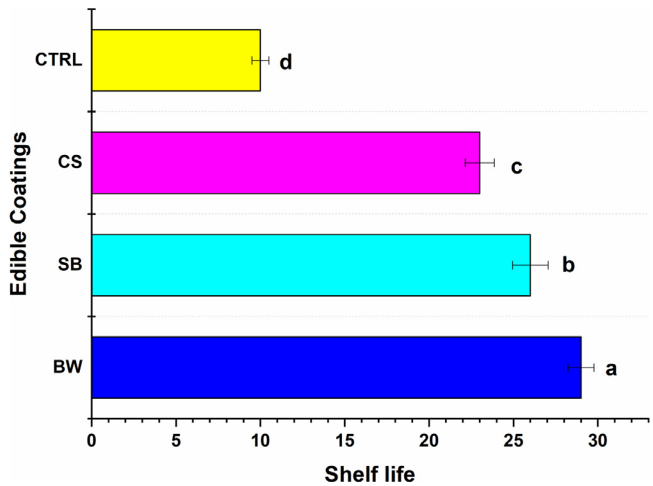


**Fig. 4.** Influence of different edible coating material on shelf life of tomato fruits.

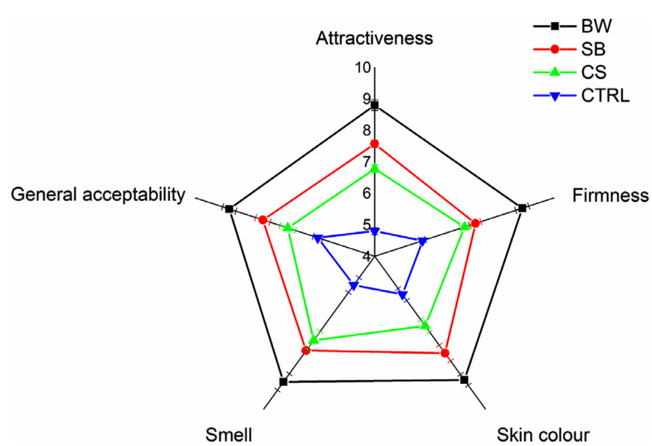


**Fig. 5.** Influence of different edible coating material on organoleptic properties of tomato fruits.

### *3.7. Effect of different waxing material on organoleptic properties*

The assessment of organoleptic and sensory properties of tomato fruits demonstrated that the edible coatings (BW, SB and CS) preserve the attractiveness, firmness, skin colour, smell and general acceptability of the coated tomato fruits compared to the uncoated fruits (Fig. 5). The uncoated fruit was less preferred by the panel and it was significantly ($P < 0.05$) different from the tomato fruits coated with BW, SB and CS. BW Coated tomato fruits was most accepted and preferred by the panel in terms of all the sensory properties compared to the other treatment (SB and CS). The possible mechanism for this outcome has been stated earlier in the other sections of this paper. Aji, Susanto, Sukma, and Ardie (2017), studied the impact of edible coating on the shelf life and sensory attributes of pummelo fruits and revealed that the BW coated pummelo fruits significantly maintained the organoleptic properties and other physical characteristics compared to the other edible coating materials employed in the study. These outcomes are consistent with earlier report of Lamptey et al. (2013), who revealed that consumers showed strong acceptability for neem palm coatings on watermelon than the control treatment. Raghav, Agarwal, and Saini (2016), also established that the application of gum Arabic edible coating improved the physicochemical characteristics and organoleptic properties of cucumber.

## 4. Conclusion

Based on the results of the current study, we can conclude that the various edible coatings (BW, SB and CS) were very effective in preserving the overall quality of the tomato fruits. All the edible coating treatment had a significant influence on the antioxidant activity (ABTS and DPPH), bioactive compounds (TPC), enzyme activity (PPO), and organoleptic properties. They also prevented weight loss, and firmness of the tomato fruits during the storage period and extended their shelf-life. BW treatment exhibited the best outcomes for all parameters assessed and therefore stands out as a good postharvest technique for tomatoes meant for storage within the time limit of this study (i.e., 20 days).

## Declaration of Competing Interest

The authors declare no conflict of interest.

## Acknowledgment

None.

## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.afres.2022.100041.

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