



## Effect of Edible Coating based on improved Cassava Starch on Post-Harvest quality of fresh Tomatoes (*solanum lycopersicum* L.)

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### Abstract

Composite coatings based on improved cassava starch have the capacity to preserve the quality and extend the shelf life of fresh tomatoes. Two new edible composite coatings C1 (4% starch/25% glycerol/5% oil/5% soybean lecithin) and C2 (4% cassava starch/microcrystalline cellulose 30%/25% glycerol/5% oil/5% lecithin) were compared with the commercially available Semperfresh™ coating and no coating. Different coatings/no coating were applied to fresh tomatoes that were subsequently stored at 20 ± 2°C and 70 ± 2% relative humidity for 4 weeks. Tomatoes coated with the composite coatings C1 and C2 based on improved cassava starch showed a significant ( $P < 0.05$ ) delay in changes of firmness, weight, titratable acidity, pH, total soluble solids, sugar/acidity ratio and colour development compared with both Semperfresh™ and uncoated control fruit. The results demonstrated that our assessed combination of improved cassava variety starch vegetable oil, glycerol, soy lecithin and cellulose and derivatives can be used as edible coating to increase the shelf life of tomatoes stored at 20 ± 2°C up to four weeks.

**Keywords:** Cassava Starch, Starch-Based Coating, Tomato; Post-Harvest Preservation, Edible Coating

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### Introduction:

The tomato (*Solanum lycopersicum* L.), an herbaceous plant of the Solanaceae family, is widely cultivated for its fruit. According to the FAO it is grown in 170 countries around the world and in various climate zones including relatively cold ones. Tomato is a climacteric fruit that continues to ripen after the harvest (Zapata et al., 2008). However, the post-harvest ripening process can lead limited shelf life and quality degradation of the fruit (Batu, 2004), resulting in crop losses between 25 and 80%, the tropics being particularly badly affected (Baldwin, 2001). Owing to consistently high temperatures, respiration is increased in tropical climate resulting in faster fruit ripening and deterioration in fruit quality (Bailén et al., 2006).

The ideal conservation method increases the shelf life of tomatoes and allows maintaining the quality for a longer period (Tasdelen and Bayindirli, 1998). In general, conservation at low temperature is used to limit the rate of respiration and thermal decomposition to increase the shelf life of tomatoes. However, prolonged storage at low temperatures causes cooling lesions and contraction of the skin when water from the skin of the fruit penetrates the pulp reducing the taste and damaging the fruit (Zapata et al., 2008). Controlled atmosphere storage, modified atmosphere packaging or food coatings have been developed as alternatives to cold storage to slow the ripening process after harvest and thus extend shelf life (Baldwin, 2001). Edible food coatings represent a modified layer in the fruit, providing the fruit with mechanical protection and a semi-permeable barrier against O<sub>2</sub> and CO<sub>2</sub> movements, controlling respiratory

exchanges, and therefore improving the conservation of fresh fruits and vegetables (Martínez-Romero et al., 2006). Several types of edible films have been successfully applied for the preservation of fresh food products (Tasdelen and Bayindirli, 1998). Edible films or coatings are thin layers of digestible material that can be applied to food products using a diversity of techniques including packaging, immersion, spraying or brushing (Donhowe and Fennema, 1994). The coatings may be of a composite nature – i.e. produced from a combination of several polymers. The combination of polymers for forming films can be derived from protein compounds and carbohydrates, protein compounds and lipid compounds, carbohydrate compounds and lipid compounds or synthetic polymers and natural polymers (Bourtoom, 2008). These combinations aim to benefit from the distinct functional characteristics and advantages of each film-forming agent category (Kester and Fennema, 1986). The purpose of this study was to evaluate whether starch-based composite coatings of improved cassava varieties have properties that allow them to be used as edible coatings to preserve the physicochemical parameters of tomatoes and prolong their life after harvest.

## Material and methods

### Sampling of tomatoes

Fresh mature tomatoes were purchased from a producer. The final batches for the study were obtained by selecting for homogeneous appearance based on color, size and absence of injury. Five batches, with 5 tomatoes each were included for evaluation for each of four coating schemes (3 coatings and 1 control). The experiment was conducted over a storage period of four weeks.

### Preparation of edible biofilms

A preparation of 4% starch/25% glycerol/5% oil/5% soybean lecithin (C1) coating was done in two steps. First, 4 g of dried cassava starch was mixed with 1 g of glycerol (w/w) and two thirds of distilled water. The mixture was heated for 20 min from 30 to 75°C with constant stirring at 750 rpm. Then, peanut oil (w/w, based on starch mass) and soy lecithin (w/w based on the amount of added oil) with 1/3 distilled water total mixture was also heated for 20 min from 30 to 75°C with constant stirring at 750 rpm. Subsequently, the peanut oil, soybean lecithin and distilled water solution was homogenized at 24,000 rpm for 2 min using Ultra Turrax T 25 (IKA-WERKE/Germany). In the second step, the homogenized solution was mixed with that of starch and glycerol and then heated from 75 to 95°C for 25 min at 750 rpm. The preparation of the gel (C2) based on 4% cassava starch/microcrystalline cellulose 30%/25% glycerol/5% oil/5% lecithin was done according to the same process as followed for the C1 gel except that the cellulose was homogenized in distilled water for 24 hours at 750 rpm and then homogenized at 13,000 rpm for 10 min prior to the preparation of the gel. The gels C1 and C2 obtained were left to cool to 30°C before coating the products. The Semperfresh™ commercial coating product consists of sucrose fatty acid esters, sodium carboxymethylcellulose and mono-di glycerides of fatty acid and is a gel that was produced at 3% (60 mL of Semperfresh™ diluted in 1 L of distilled water).

### Coating of fresh tomatoes

Tomatoes of the same size and shape, uniform in colour and free of defects were harvested from a local field. The pool of fruits was divided to obtain 20 fruits for each of the four different coating groups, namely Semperfresh™ coating, C1 and C2 coating (both starch formulations) and uncoated controls. The tomatoes were washed with water and dried at ambient air conditions before coating in order to enable adherence to the surface. Fruits with hooks on the peduncle were immersed in the different solutions for 30 s, left to drain and

then dried overnight before the tests. Samples were stored in a compartmented cupboard at 20 ± 2°C and 70 ± 2% relative humidity.

### Determination of weight loss

The weight loss was determined by the method described by Athmaselvi and colleagues (Athmaselvi et al., 2013). Five tomatoes of each batch were taken and the mass of the coated and uncoated tomatoes was recorded after drying of the coating (T<sub>0</sub>) and then weekly for 4 weeks (T<sub>1</sub>, T<sub>2</sub>, T<sub>3</sub> and T<sub>4</sub>). The cumulative mass losses were calculated according to the following equation:

$$\text{Weight loss (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Final weight}} \times 100$$

### Determination of tomato colour

The colour of the tomato was measured using a Hunter colorimeter (ColorFlex EZ 380, Virginia/USA). The average value of L\* (white to black), a\* (yellow to blue), b\* (green to red) values was measured and the chroma value (ΔE) was calculated using the equation given below (Andres et al., 2004).

$$\Delta E = \sqrt{(L^*)^2 + (a^*)^2 + (b^*)^2}$$

### Tomato firmness

The firmness of the tomatoes was analyzed using a TA-XT2 texture analyzer (Stable Microsystems Ltd, UK). Tomatoes were placed in the center of the platform and the force applied by the blade to slice the tomato at 30 mm at rate of 0.5 mm/s was measured.

### Concentration of soluble solids

The total soluble solids concentration (%) was determined at 22°C using an ATAGO DBX-55 digital refractometer (Japan) by using 2 to 3 drops of juice obtained by pressing the fruit (AOAC, 1994).

### Titrateable acidity and pH

A 10-mL sample of tomato juice obtained by using an extractor was taken from a 250-mL beaker. Then, 50 mL of distilled water were added and the resulting solution was titrated with 0.1 N NaOH according to the Association of Official Analytical Chemists AOAC (Association of Official Analytical Chemists AOAC, 1999). The results are expressed as percent citric acid present in the samples. The determination of the pH was carried out directly in the solution used for the determination of titrateable acidity, using a pH meter.

### Statistical analysis

Multivariate analysis of variance (MANOVA) was used to compare differences between means using the STATISTICA 7.1 software (StatSoft, France, Statistica, 2005). The DUNCAN test was applied to determine differences at a 5% threshold. In addition, the correlation coefficient among the quality parameters of weight loss, total soluble solids, pH, titrateable acidity, and report sugar/acidity in control (uncoated tomatoes) and Semperfresh, C1 and C2 coated tomatoes was analysed.

## Results and discussion

### Weight loss of tomatoes

The weight loss of coated and uncoated tomatoes is represented in Fig 1. Tomatoes coated with C1 and C2 gel experienced less weight loss during storage than uncoated control samples and those coated with Semperfresh™ (P < 0.05). Compared with each other, the coatings

based on cassava starch (C1 vs C2) had the same effect on the weight loss of the tomatoes.

The reduction in weight loss of tomatoes with coating gels compared with uncoated tomatoes was certainly related to the effects of the coating. Cassava starch coatings have previously been shown to be a good semi-permeable barrier against O<sub>2</sub> and CO<sub>2</sub> exchanges and moisture in coated tomatoes. Thus, the rates of respiratory reaction, loss of water and oxidation were reduced (Baldwin et al., 1999; Park, 1999). The reduction of the weight loss of tomatoes coated with starch gels could also be related to the thickness and water permeability

of gels, which are important factors in terms of mass transfer rate. Indeed, the main mechanism of weight loss is related to the local vapor pressure of fresh fruits and vegetables (Yaman and Bayindirli, 2002). It is furthermore related to gas exchange which also results in weight reduction (Pan and Bhowmilk, 1992). The results on weight loss of this study are in agreement with the findings from another research team on the use of alginate and zein as edible coating on tomato (Zapata et al., 2008) and also work on edible coating based on gum arabic to improve shelf life and improve post-harvest quality of tomato fruit (Ali et al., 2010).

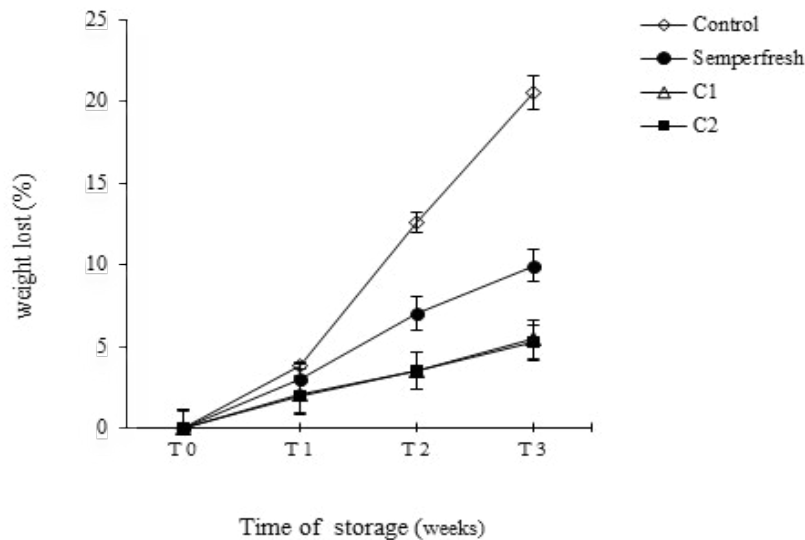
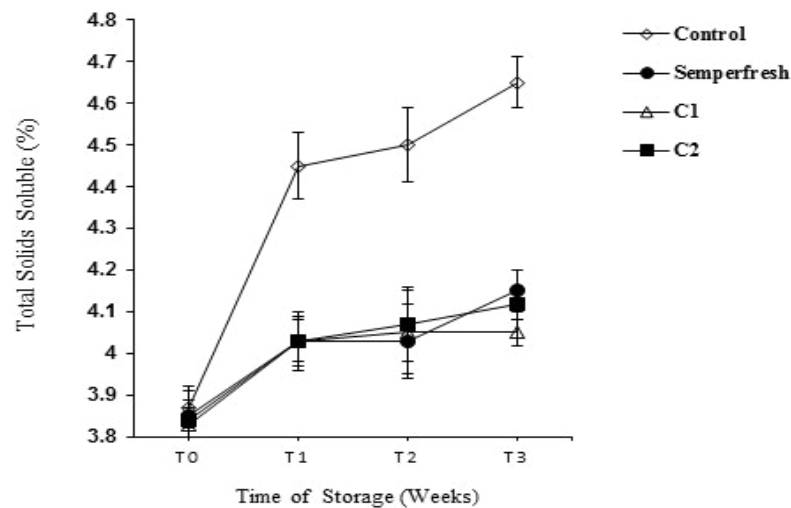


Fig. 1 Weight loss of coated and uncoated tomatoes as a function of storage time

### Total soluble solids

Figure 2 represents the soluble solids of coated and uncoated tomatoes and their changes during storage. The composite coatings based on cassava starch reduced the total soluble solids production significantly compared with the control samples where the increase was high ( $P < 0.05$ ). C1, C2 were equivalent and C1 was found to be statistically different from Semperfresh™ ( $P < 0.05$ ). On the other hand, for the T1 and T2 storage periods the increase was not found to be significant for the control and Semperfresh™ groups. For C1 and C2, the increase in total soluble solids was not significant at T1, T2, and T3. Overall, total soluble solids increased with continuing storage time. Total soluble solids increased sharply with the controls from 3.87% to 4.65% at T0 and T3. On the other hand, for Semperfresh™, C1 and C2 the increase was small increasing from 3.85% at T0 to 4.15% at T3 for Semperfresh™; from 3.83% to 4.05% for C1 and from 3.84% to 4.11% for C2. The increase in total soluble solids was significantly elevated during storage in uncoated tomatoes as observed previously (Ali et al., 2010; Bico et al., 2009; Das et al., 2013). The control sample showed

a higher increase in total soluble solids followed by samples coated with Semperfresh™, C2 and C1 and those at time T3. However, the total soluble solids content remained unchanged at storage periods, at T1 and T2 for Semperfresh™, T1, T2 and T3 for C1 and C2 which is also in agreement with previous observations (Bico et al., 2009; Das et al., 2013). The evolution of total soluble solids is a function of the hydrolytic changes of polysaccharides such as starch and maturation during post-harvest storage. The degradation of starch into sugar is an important indicator of tomato ripening (Kays, 1997). The degradation of hemicelluloses and pectins in the cell wall that occurs during storage results in the release of oligosaccharides. This can influence fruit ripening (Cote and Hahn, 1994). Coatings have proven to be an excellent barrier around the fruit, altering the internal atmosphere by decreasing O<sub>2</sub> and/or increasing CO<sub>2</sub> and limiting ethylene production (Ali et al., 2010). Reduced gas exchange (O<sub>2</sub>/CO<sub>2</sub>) rates also slow the synthesis and use of metabolites, resulting in a decrease in total soluble solids (Yaman and Bayindirli, 2002). The results of this study are consistent with those of Das et al., (2013) who used rice starch as coating on tomatoes.



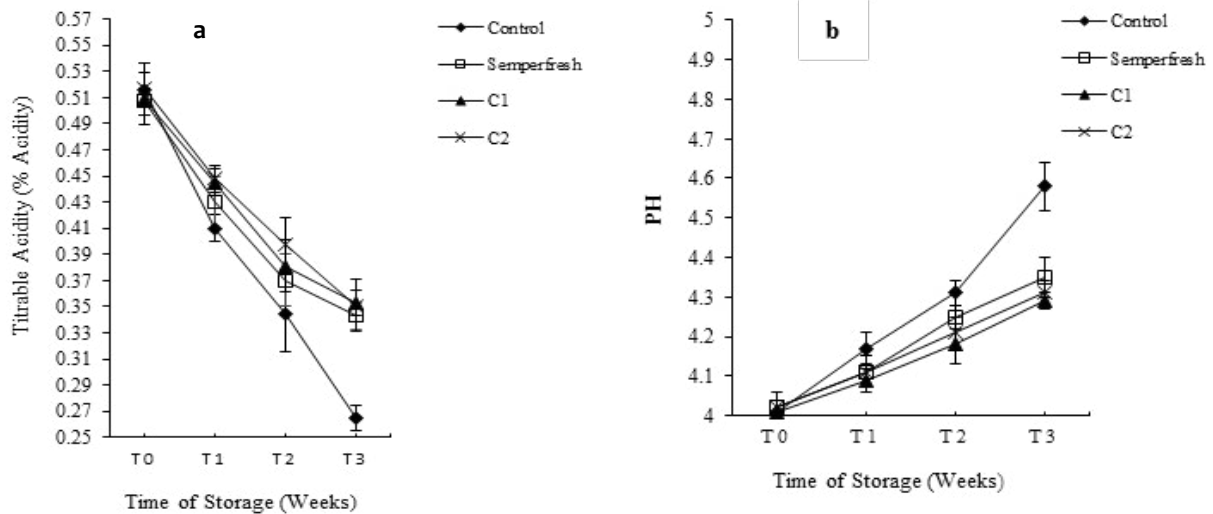
**Fig. 2.** Total soluble solids of coated and uncoated tomatoes as a function of storage time

### Titrateable acidity and pH

Titrateable acidity decreased significantly with storage time in the control and coated samples ( $P < 0.05$ ). However, the acidity was different from T<sub>0</sub> to T<sub>3</sub> in the uncoated tomatoes compared with tomatoes coated with Semperfresh™, C1 and C2 (Fig. 3a). The cassava-based coatings were statistically equivalent but differed from the Semperfresh™ and the control group. The starting acidity at T<sub>0</sub> was 0.516%, 0.507%, 0.509% and 0.517% for the controls, Semperfresh™, C1 and C2, respectively. At T<sub>3</sub> values decreased significantly to 0.265%, 0.343%, 0.353% and 0.351%. The pH increased significantly during storage in coated and uncoated tomatoes ( $P < 0.05$ ). The difference was significant from T<sub>0</sub> to T<sub>3</sub> for all coatings (C1, C2 and Semperfresh™) and the controls (Fig. 3a). The coatings C1 and C2 were statistically identical in maintaining the pH and different from the control

and the Semperfresh™ coating. The pH varied from 4.01 at T<sub>0</sub> to 4.58, 4.35, 4.29 and 4.31 at T<sub>3</sub> for control, Semperfresh™, C1 and C2 respectively.

In general, the decrease in acidity over time seems more pronounced in uncoated tomatoes compared with coated tomatoes and may be related to high ethylene production and respiration rate during ripening (Das et al., 2013; Oz and Ulukanli, 2011). The less pronounced decrease in titrateable acidity in coated tomatoes indicates the effectiveness of coating films in reducing ethylene production, which accelerates the maturation of the fruit (Das et al., 2013). The pH of the tomatoes increased during storage while the titrateable acidity decreased. Some authors attributed such opposite changes to the loss of citric acid in tomatoes (Anthon et al., 2011; Das et al., 2013).



**Fig. 3.** Titrateable acidity (a) and pH (b) of the coated tomatoes and uncoated as a function of the storage time

### Report sugar/acidity

The sugar/acidity ratio values of coated and uncoated tomatoes during storage are shown in Table 1. The difference was significant from T<sub>0</sub> to T<sub>3</sub> for the coatings (C<sub>1</sub>, C<sub>2</sub> and Semperfresh™) and the controls ( $P < 0.05$ ). The coatings C<sub>1</sub> and C<sub>2</sub> were statistically identical and different from the control and the Semperfresh™ coating in maintaining the degree of maturation of the tomatoes. The sugar/acidity ratio between T<sub>0</sub> and T<sub>3</sub> ranged from 7.49% to 16.31%, 7.60 to 11.97%, 7.53 to 11.47% and 7.42 to 11.73%, for the control samples, Semperfresh™, C<sub>1</sub> and C<sub>2</sub>. The sugar/acidity ratio increased over time with a more pronounced

trend in uncoated tomatoes and least pronounced in the starch-based coatings. The sugar/acidity ratio is an indicator of commercial maturity and fruit consumption being relatively low at the beginning of ripening owing to a low sugar and a high acid content. However, during the maturation process, the acids are degraded leading to increasing sugar content. A larger value of the sugar/acidity ratio is indicative of a mild flavour, while low values indicate an acidic flavour (Bolzan, 2008). The coatings based on improved cassava starch of this study allowed the acidity of tomatoes to be maintained during storage. Our results are consistent with those of Reis et al. (2015).

Storage time	Control n=3	Semperfresh™ n=3	C1 n=3	C2 n=3
T <sub>0</sub>	7.49±0.1 <sup>a</sup>	7.60±0.1 <sup>a</sup>	7.53±0.1 <sup>a</sup>	7.42±0.1 <sup>a</sup>
T <sub>1</sub>	9.46±0.1 <sup>b</sup>	9.59±0.2 <sup>b</sup>	9.69±0.2 <sup>b</sup>	9.64±0.3 <sup>b</sup>
T <sub>2</sub>	13.07±0.3 <sup>c</sup>	10.90±0.1 <sup>c</sup>	10.63±0.2 <sup>c</sup>	10.21±0.2 <sup>c</sup>
T <sub>3</sub>	16.31±0.3 <sup>d</sup>	11.97±0.4 <sup>d</sup>	11.47±0.1 <sup>d</sup>	11.73±0.1 <sup>d</sup>
T <sub>4</sub>	nd	15.84±0.1 <sup>e</sup>	12.43±0.2 <sup>e</sup>	12.98±0.1 <sup>e</sup>

**Table. 1** Values of the ratio sugar/acidity of coated and uncoated control tomatoes according to storage time. nd, not determined; T<sub>0</sub>, day of start of storage period, T<sub>1</sub>–T<sub>4</sub>, 1 to 4 weeks of storage. The values with different letters in the same column are statistically different ( $P < 0.05$ ).

### Tomatoes firmness

Firmness decreased significantly with storage time in control and coated samples (C<sub>1</sub>, C<sub>2</sub> and Semperfresh™) ( $P < 0.05$ ). The values were statistically different from T<sub>0</sub> to T<sub>3</sub> for the coatings (C<sub>1</sub>, C<sub>2</sub> and Semperfresh™) and the controls (Table 2). The coatings C<sub>1</sub> and C<sub>2</sub> were statistically identical but differed from the controls in maintaining the firmness. C<sub>2</sub> differed statistically from Semperfresh™ in maintaining firmness. Values ranged from 89.14 ± 2.4 N to 38.24 ± 1.3 N, 90.38 ± 0.8 N at 50.87 ± 1.2 N, 90.83 ± 1.8 N and 90.96 ± 1.1 N at 55.22 ± 3.9 N for the control samples, Semperfresh™, C<sub>1</sub> and C<sub>2</sub> to T<sub>0</sub> and T<sub>3</sub>, respectively. The observed decrease was higher at the control level than in coated tomatoes with no evident difference between the coatings. Firmness is an important indicator for determining the degree of maturation. Therefore, greater maturity means less firmness and less resistance when force is applied (Jimenez et al., 2015). Zapata et al., (2007) noted the influence of corn zein coating on decreased degradation of cell wall compounds due to hydrolysis. This hydrolysis produces softening, and conversion of the starch into sugars (Khurnpoo et al., 2008). The

degradation of cell structure, cell wall composition and intracellular compounds leads to fruit softening (Seymour et al., 1993). This biochemical process is due to the action of wall hydrolases, which are enzymes that hydrolyze pectin and starch (Ali et al., 2010). The elevated activities of the pectinesterase and polygalacturonase enzymes result in depolymerization or shortening of pectin chain length at the fruit level, as the fruit ripening process increases (Yaman and Bayindirli, 2002). The activities of these enzymes are limited by low levels of O<sub>2</sub> and high levels of CO<sub>2</sub>, which leads to retention of fruit firmness during storage (Salunkhe et al., 1991). The coatings seem to have reduced the respiration rates of the coated tomatoes, thus causing a delay in maturation which has resulted in firmness retention during storage. It has been previously reported that respiration and O<sub>2</sub> consumption were lower in tomatoes coated with maize zein gel than in uncoated tomatoes (Park et al., 1994). Moreover, the decrease in firmness of uncoated and coated tomatoes has been observed in multiple studies (Ali et al., 2010; Athmaselvi et al., 2013; Jimenez et al., 2015; Zapata et al., 2008).

Storage time	Control n=3	Semperfresh™ n=3	C1 n=3	C2 n=3
T0	89.14±2.4 <sup>a</sup>	90.38±0.8 <sup>a</sup>	90.83±1.8 <sup>a</sup>	90.96±1.1 <sup>a</sup>
T1	70.98±1.7 <sup>b</sup>	72.27±1.9 <sup>b</sup>	73.10±2.1 <sup>b</sup>	74.95±2.5 <sup>b</sup>
T2	54.77±5.7 <sup>c</sup>	60.27±1.9 <sup>c</sup>	61.18±4.5 <sup>c</sup>	62.67±1.7 <sup>c</sup>
T3	38.24±1.3 <sup>d</sup>	50.87±1.2 <sup>d</sup>	54.06±4.1 <sup>d</sup>	55.22±3.9 <sup>d</sup>
T4	nd	44.50±1.6 <sup>e</sup>	52.08±2.8 <sup>e</sup>	53.56±3.1 <sup>e</sup>

**Table 2** Firmness values of coated and uncoated tomatoes at different storage times. nd: not determined, T<sub>0</sub>: day of start of storage period, T<sub>1</sub>–T<sub>4</sub>: 1 to 4 weeks of storage. The values with different letters in the same column are statistically different ( $P < 0.05$ ).

### Colour parameters

The values of the color parameters of coated and uncoated tomatoes at different storage times are presented in Table 3. The L\* (white to black) and b\* (yellow to red) parameters decreased significantly with shelf-life in coated and uncoated tomatoes ( $P < 0.05$ ). On the other hand, the index a\* (green to blue) and the color difference  $\Delta E^*$  increased significantly during storage time ( $P < 0.05$ ). The coatings C1 and C2 have identically influenced the parameter b\*. On the other hand, for the other parameters the influences were statistically different. Compared with the control and the Semperfresh™ coating, the effects were statistically different. The decrease in L\* and b\* parameters was less with coated tomatoes. On the other hand, the diminution was accelerated at the level of the witness comparatively. Similarly, the increase in the a\* index and the color difference  $\Delta E^*$  was less in the coated tomatoes, compared with the control. The values of the index L\* were 58.65, 58.17, 58.65, 58.66 for T<sub>0</sub> and 34.83, 33.14, 38.10, 39.26 for T<sub>3</sub> for the control, Semperfresh™, C1 and C2, respectively. The values of the index a\* were -2.31, -2.26, -2.29, -2.26 for T<sub>0</sub> and 34.28, 24.52, 21.39, 20.83 for T<sub>3</sub> for the control, Semperfresh™, C1 and C2, respectively. For the index b\* the values were 25.42, 25.25, 25.39, 25.34 for T<sub>0</sub> and 9.73, 18.57, 20.38, 20.30 for T<sub>3</sub> for the control, Semperfresh™, C1 and C2, respectively. The values of the color difference  $\Delta E^*$  to T<sub>0</sub> and T<sub>3</sub> were 25.52, 25.35, 25.49, 25.44 and 35.64, 30.76, 29.55, 29.08 for the control, Semperfresh™, C1 and

C2, respectively. The color index L\* indicates the change from white to black. Generally, when the red pigments begin to be synthesized, there is a decrease in the L\* value as reported previously with the index a\* changing from negative (green) to positive (red) (Andres et al., 2004; Athmaselvi et al., 2013). The value  $\Delta E^*$  depends on the values a\* and b\*. The value  $\Delta E^*$  indicates the color intensity (saturation) of the sample (Athmaselvi et al., 2013). Colour is an important criterion for the quality and acceptability of the consumer, particularly for tomatoes (Aked, 2000). The change from green to yellow or red at the fruit level corresponds to the drop-in chlorophyll pigments and increased carotenoid synthesis (Pretel et al., 1995). During the ripening process, there is degradation of the chlorophyllian green pigment and an accumulation of carotenoids, namely lycopene which is responsible for the red coloring of ripe tomatoes (Khudairi, 1972). During the maturation of tomatoes, high levels of CO<sub>2</sub> decrease the synthesis of ethylene, which can delay colour changes (Buescher, 1979). In this study, the coatings delayed a change in colour of the tomatoes. A similar result was reported by Ali et al., (2010). They attributed the retardation of color change to the action of the coating of gum arabic which probably allowed an increase of CO<sub>2</sub> and a decrease of the levels of O<sub>2</sub>. The values a\* as already indicated, show change colour from green through red (negative to positive) clearly indicated that the coatings had reduced synthesis of carotenoid compounds in tomatoes retarding color change during storage (Das et al. 2013).

Color Parameters	Storage time	Control n=3	Semperfresh™ n=3	C1 n=3	C2 n=3
L*	T0	58.65±0.1 <sup>a</sup>	58.17±0.3 <sup>a</sup>	58.65±0.1 <sup>a</sup>	58.66±0.1 <sup>a</sup>
	T1	40.40±0.2 <sup>b</sup>	44.61±0.7 <sup>b</sup>	47.55±0.5 <sup>b</sup>	47.63±0.1 <sup>b</sup>
	T2	37.13±0.1 <sup>c</sup>	40.45±0.3 <sup>c</sup>	41.49±0.2 <sup>c</sup>	41.24±0.2 <sup>c</sup>
	T3	34.83±0.3 <sup>d</sup>	33.14±0.1 <sup>d</sup>	38.10±0.1 <sup>d</sup>	39.26±0.1 <sup>d</sup>
	T4	nd	30.17±0.1 <sup>e</sup>	34.54±0.1 <sup>e</sup>	35.15±0.1 <sup>e</sup>
a*	T0	-2.31±0.1 <sup>a</sup>	-2.26±0.1 <sup>a</sup>	-2.29±0.1 <sup>a</sup>	-2.26±0.1 <sup>a</sup>
	T1	17.32±0.1 <sup>b</sup>	15.48±0.2 <sup>b</sup>	13.44±0.1 <sup>b</sup>	13.15±0.1 <sup>b</sup>
	T2	25.28±0.2 <sup>c</sup>	19.31±0.1 <sup>c</sup>	17.95±0.1 <sup>c</sup>	17.25±0.1 <sup>c</sup>
	T3	34.28±0.3 <sup>d</sup>	24.52±0.1 <sup>d</sup>	21.39±0.2 <sup>d</sup>	20.83±0.2 <sup>d</sup>
	T4	nd	34.62±0.1 <sup>e</sup>	27.43±0.2 <sup>e</sup>	26.80±0.2 <sup>e</sup>
b*	T0	25.42±0.1 <sup>a</sup>	25.25±0.1 <sup>a</sup>	25.39±0.2 <sup>a</sup>	25.34±0.1 <sup>a</sup>
	T1	22.77±0.1 <sup>b</sup>	23.11±0.1 <sup>b</sup>	24.35±0.1 <sup>b</sup>	24.33±0.2 <sup>b</sup>
	T2	16.56±0.2 <sup>c</sup>	20.34±0.1 <sup>c</sup>	22.15±0.2 <sup>c</sup>	21.98±0.2 <sup>c</sup>
	T3	9.73±0.3 <sup>d</sup>	18.57±0.2 <sup>d</sup>	20.38±0.2 <sup>d</sup>	20.30±0.2 <sup>d</sup>
	T4	nd	15.57±0.2 <sup>e</sup>	17.15±0.2 <sup>e</sup>	16.97±0.3 <sup>e</sup>
ΔE*	T0	25.52±0.1 <sup>a</sup>	25.35±0.1 <sup>a</sup>	25.49±0.2 <sup>a</sup>	25.44±0.1 <sup>a</sup>
	T1	28.61±0.1 <sup>b</sup>	27.81±0.2 <sup>b</sup>	27.81±0.1 <sup>b</sup>	27.65±0.1 <sup>b</sup>
	T2	30.22±0.1 <sup>c</sup>	28.04±0.1 <sup>c</sup>	28.51±0.1 <sup>c</sup>	27.94±0.2 <sup>c</sup>
	T3	35.64±0.2 <sup>d</sup>	30.76±0.1 <sup>d</sup>	29.55±0.1 <sup>d</sup>	29.08±0.2 <sup>d</sup>
	T4	nd	37.96±0.2 <sup>e</sup>	32.35±0.1 <sup>e</sup>	31.72±0.3 <sup>e</sup>

**Table 3** Values of color parameters of coated and uncoated tomatoes at different storage times. nd: not determined, T<sub>0</sub>: day of start of storage period, T<sub>1</sub>–T<sub>4</sub>: 1 to 4 weeks of storage. The values with different letters in the same column are statistically different (P < 0.05).

### Relationship between changes in the different quality parameters of uncoated tomatoes, tomatoes coated with Semperfresh™, C1 and C2

The values of the Pearson correlation coefficients for the relationship between changes in the different quality parameters of uncoated tomatoes, tomatoes coated with Semperfresh™, C1 and C2 are presented in Table 4. Weight loss and titratable acidity were negatively correlated with uncoated tomatoes and those coated with Semperfresh™, C1 and C2. With weight loss increasing from T<sub>0</sub> to T<sub>3</sub>, the titratable acidity decreased from T<sub>0</sub> to T<sub>3</sub> during storage. In contrast to titratable acidity, weight loss and total soluble solids, the sugar/acidity ratio and pH were positively correlated in uncoated tomatoes as coated with Semperfresh™, C1 and C2. When weight

loss increases total soluble solids, the sugar/acidity ratio and pH also increase during storage. Titratable acidity is negatively correlated with total soluble solids, sugar/acidity ratio and pH in uncoated tomatoes coated with Semperfresh™, C1 and C2. When the titratable acidity decreases from T<sub>0</sub> to T<sub>3</sub>, the total soluble solids, the sugar/acidity ratio and the pH increase from T<sub>0</sub> to T<sub>3</sub> during storage. The total soluble solids, the sugar/acidity ratio, the pH was positively correlated in the uncoated tomatoes and coated with Semperfresh™, C1 and C2. When total soluble solids increase in coated and uncoated tomatoes, the sugar/acidity ratio and pH also increase with storage time. The sugar/acidity ratio and pH were also positively correlated in uncoated tomatoes and coated with Semperfresh™, C1 and C2. When the sugar/acidity ratio increases, the pH also increases during storage (T<sub>0</sub> to T<sub>3</sub>).

Correlation coefficients	Titrable acidity (%)	Soluble Solids Total (%)	Report S/A (%)	pH
Control				
Weight lost (%)	-0.99	0.81	1	0.94
Titrable acidity (%)		-0.82	-0.99	-0.97
Soluble Solids Total (%)			0.84	0.7
Report S/A (%)				0.94
Semperfresh				
Weight lost (%)	-0.96	0.86	0.98	0.99
Titrable acidity (%)		-0.9	-0.99	-0.97
Soluble Solids Total (%)			0.93	0.83
Report S/A (%)				0.98
C1				
Weight lost (%)	-0.96	0.76	0.97	0.95
Titrable acidity (%)		-0.89	-1	-0.9
Soluble Solids Total (%)			0.89	0.69
Rapport S/A (%)				0.91
C2				
Weight lost (%)	-0.97	0.89	0.98	0.97
Titrable acidity (%)		-0.94	-0.99	-0.89
Soluble Solids Total (%)			0.94	0.8
Report S/A (%)				0.92

**Table 4:** The values of the Pearson correlation coefficients for the relationship between changes in the different quality parameters of uncoated tomatoes, tomatoes coated with Semperfresh™, C1 and C2.



## Conclusion

The results of this study indicate that cassava starch coatings assessed significantly delay the weight change, the progressing colouration, degradation of firmness, drop of titratable acidity, increase of total soluble solids concentration and pH during tomato storage at 22°C compared with uncoated control fruits. In general, the cassava-based coatings allowed the preservation of fresh tomatoes for up to one month while maintaining the different key quality parameters. Further studies should be conducted on the gas exchange of cassava starch-based coatings in relation to the development of new formulations and their application to various climacteric fruits and vegetables, plantain and fresh cassava roots. Research is also needed to influence these coatings on microbial growth by providing essential oils with antibacterial and antioxidant properties and the physiological processes of maturation.

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