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Comparative Preservative Potentials of *Solanum Lycopersicum* Fruit with Polymers of Turmeric and Thyme Essential Oil

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Abstract
The qualities of fruit grown in developing nations are lost before being consumed, primarily as a result of high rates of bruising, water losses and subsequent deterioration during postharvest handling. One of such important fruit that is highly perishable, susceptible to microbial spoilage and enzymatic degradation is Tomato (*Solanum lycopersicum*). In this study, Thyme and turmeric essential oils were embedded in chitosan-alginate complexes and their preservative potentials on tomato fruits during storage were comparatively studied in fourteen days. Percentage weight loss, polygalactorunase, polyphenol oxidase, peroxidase activities, ascorbic acid and lycopene contents, total antioxidant capacity (TOC) and browning index of the preserved tomatoes were evaluated on seventh and fourteenth (14th) day. Generally, all the parameters studied were better with the thyme essential oil complex coatings particularly with the chitosan-alginate-thyme (CH-AG-TH) coating. Hence, it was concluded that thyme essential oil embedded in chitosan arginate complex is better for the preservation of tomato fruits than the turmeric essential oil-based coatings.

Keywords: thyme essential oil, turmeric essential oil, tomato, chitosan, alginate

Introduction
Important qualities of products grown in developing nations are lost before they can be consumed, primarily as a result of high rates of bruising, water loss, and subsequent deterioration during postharvest handling (Imathiu, 2021; Kitinoja and Kader, 2002). Significant loss in fresh produce is nutritional loss (loss of vitamins, antioxidants, and health-promoting compounds) or lower market values are results of a variety of factorial influences. The rate of degradation and rotting is determined by the sum of all of these effects (Siddiqui *et al.* 2014). Porat *et al.* (2018) estimates that almost one-third of all fresh fruits and vegetables are lost before they are consumed.

According to a different estimate, between harvest and ultimate consumption, fruits and vegetables lose between 30 and 40 per cent of their overall production values (Salami *et al.* 2010). As soon as tomato is harvested, the quality begins to deteriorate, continuing until it is eaten or, if not, spoils. The success and high productivity rate any fresh produce company plan's success or failure is entirely based on how well those produce are managed. Moreover, the emergence of corona virus pandemic has raised an alarming global situation for the supply chain of agro food, including fresh fruits and vegetables (de Assis *et al*., 2022) and to this chain of supply to be sustained, sustainable preservative techniques that reduces the postharvest loss and wastages (Lopez-Polo *et al*., 2020). Tomato (*Solanum lycopersicum)* is one of the most popular and widely consumed fruits in the world due to its nutritional value, taste, and versatility in cooking. However, its short shelf life is a significant challenge for both producers and consumers. The post-harvest losses of tomato fruits can be significant, leading to economic losses for farmers and increased food waste (Njume *et al.,* 2020). Therefore, it is crucial to find effective and sustainable methods of extending the shelf life of tomato fruits.

Various synthetic preservatives, such as sodium benzoate, sodium nitrite, and potassium sorbate, have earlier been used to prolong the shelf-life of tomatoes (Ogunnupebi *et al.,* 2020). These chemicals are known to cause harmful effects on human health and the environment (Chen *et al.,* 2022). One promising approach to extending the shelf life of fruits and vegetables is the use of natural compounds such as essential oils. Essential oils are volatile aromatic oils from plant extracts. They are so named because they contain biochemical essentials of plants and its fragrance (Laranjo *et al.,* 2017).

Thyme essential oil (TEO) is a volatile oil extracted from the *Thymus vulgaris* plant that has been reported to have antimicrobial, antioxidant, and antifungal properties. Thyme oil has demonstrated excellent antimicrobial activity against various foodborne pathogens, such as *Escherichia coli* and *Salmonella enterica,* and has been found to be safe for human consumption (Friedman *et al.,* 2017). *Curcuma longa L. (Curcuma domestica)*, commonly known as turmeric, is a perennial herb native to Asia usually used as a dye, cosmetic, and food seasoning. In traditional medicine, turmeric is used for treating hepatic and gastrointestinal disorders, arthritis, rheumatism, skin diseases, fever, inflammation, amenorrhea, sepsis, and as an anthelmintic and laxative (Dosoky and Setzer, 2018; Villegas, *et al*., 2008). Some of these properties are supported by scientific evidence, and other novel activities have also been uncovered. Dried rhizomes contain about 3–6% essential oil (Bampidis *et al*., 2020).

Edibility and biodegradability are the most beneficial characteristics of edible films and coatings. Edibility of films and coatings could be achieved if films and coatings components including biopolymers, plasticizers, and other additives of food grade ingredients with toxicity and environmental safety evaluated by standard analytical protocols (Han, 2014). Incorporation of essential oils into food products is limited by their volatile and unstable nature and potential interactions with food components. Preservation using biodegradable polymers has been proposed as a solution to these challenges, hence the need to evaluate the effectiveness of different polymers for encapsulating essential oil for tomatoes preservation.

Chitosan: a biopolymer derived from chitin, is another natural compound that has been shown to possess antimicrobial properties. In recent years, there has been growing interest in developing new technologies to preserve the quality and extend the shelf life of tomato fruits using natural compounds such as TEO and chitosan and its polymers. This research is aimed at investigating the potential of polymer complex-loaded TEO to develop a natural preservative for tomato fruit, thus contributing to the development of effective and sustainable natural tomato preservatives for commercial application, addressing both food safety concerns and environmental sustainability requirements.

Materials and Methods

Chemicals and Reagents: Chitosan and Alginate were products of Sigma Aldrich, Switzerland. Thyme and turmeric essential oil were products of Blomera Wellness Nigeria Limited. Other chemicals and reagents that were used are of analytical grade.

Experimental Design: Two hundred and forty (240) matured ripe tomato fruits (*Solanum lycopersicum)* with authentication number UILH/001/1350/2023 free from blemishes, apparent disease, insect, and mechanical damage were procured from the Mandate market in Ilorin.

Tomato Grouping and Treatment: Two hundred and forty (240) matured ripe tomato fruits were used. The fruits were randomly grouped into eight groups of 10 fruits each and with three replicate baskets (Table 1).

Table1: Experimental Design

Groups	Description
A (Uncoated)	Were not coated with any preservative.
B (Chitosan)	Were coated with chitosan.
C (Alginate)	Were coated with Alginate
D (CH-AG)	Were coated with chitosan and Alginate
E (CH-AG-TH)	Were coated with chitosan alginate and thyme essential oil complex
F(AG-CH-TH)	Were coated with alginate, chitosan and thyme essential oil complex.
G(CH-AG-TM)	Were coated with chitosan alginate and turmeric essential oil complex
H(AG-CH-TM)	Were coated with alginate, chitosan and turmeric essential oil complex.

After the application of the polymer complex, the fruits were drained, air-dried, and placed in plastic baskets for fourteen days. Tomato fruits were weighed before and after coating. Initial samples were taken to the laboratory for analyses after being weighed. At intervals of seven days of coating, 3 samples each were randomly picked for analyses.

Preparation of Chitosan Coating: Chitosan coating was prepared according to Vargas *et al.* (2006). Briefly, a gram of chitosan (1% w/v) (Sigma Aldrich, Switzerland) was dispersed in an aqueous solution of ascorbic acid (2% v/v) and stirred on a magnetic stirring plate for a few minutes until the solution became clear.

Preparation of Alginate Coating: Alginate coating was prepared according to Rojas-Grau *et al.,* (2007). Briefly, a gram of sodium alginate ($NaC_6H_7O_6$, BDH, Poole, England) was dissolved in 100 ml sterilized distilled water and stirred on a magnetic stirring plate (Searchtech Instruments Model 78HW-1) for few minutes with heat at 45°C until the solution became clear.

Preparation of Essential Oil: Essential oil solution was prepared using the method suggested by Lert-sutthiwong *et al.* (2009). 640µl oil was dissolved in 1mL of 1% (w/v) Tween-20. Then, the mixture was added to 100ml of distilled water.

Preparation of Basil Essential oil loaded Chitosan-alginate Complex: 1000ml of the polymer complex was prepared; 320ml of ALG was diluted with 480ml of TPP. Thereafter, 150ml of CHT was diluted with 50ml of EO. The mixture of CHT+EO was added drop wisely to the ALG+TPP in the beaker with concurrent mixing on a mixer (Akolade *et al.* 2017).

Preparation of Basil Essential oil loaded Alginate-chitosan complex: 1000ml of the polymer complex was prepared; 320ml of CHT was diluted with 480ml of $CaCl_2$. Thereafter, 150ml of ALG was diluted with 50ml of EO. The mixture of ALG + EO was added drop wisely to the CHT + $CaCl_2$ in the beaker with concurrent mixing on a mixer (Akolade *et al.* 2017).

Coating Procedure for Tomato Fruits: Tomato fruits were coated in a sterile area by immersing them in various coating formulations for 20-30 seconds. Fruits were removed, air-dried, and placed in plastic baskets (Lee *et al.* 2016).

Determination of Physiological Loss in Weight: Tomato fruits were weighed using Analytical Mettler Balance and the total weight loss were calculated and expressed as a percentage of the fresh weight.

$$WL\ (\%) = \frac{\text{Fresh weight of sample - final weight of sample}}{\text{Fresh weight of sample}} \times 100$$

Biochemical Examination: Tomatoes microbial count was evaluated for fungal contamination using the standard plate count method (Dahal, 2022). Polygalacturonase (PG) activity was determined by the method of Sakai and Okushima, (1982). Polygalacturonase (PG) activity was verified by the method of Sakai and Okushima (1982). Polyphenol Oxidase Activity was verified with the method of Adamson and Abigor (1980). The method of Reddy *et al.* (1995) was adopted for assaying the activity of peroxidase. The Omaye *et al.* (1979) method was used to estimate the amount of ascorbic acid. Lycopene concentration was verified by the method of Fish *et al.* (2002). Method of McDonald *et al.* (2001) was used to calculate total phenol. The method of Prieto *et al.* (1999) was used to calculate total antioxidant capacity.

Data Analysis: The data generated from the study were three replicates' mean ± standard error of the mean, and one-way Analysis of Variance (ANOVA) was performed. With GraphPad Prism version 6.01 (GraphPad Software, Inc., San Diego, California, USA), the data was deemed statistically different at ($p < 0.05$).

Results

Percentage Weight Loss

The Percentage weight loss was significantly ($p < 0.05$) reduced by all the coating complexes except alginate on the 7th day while all coated groups were significantly ($p < 0.05$) reduced on the 14th day with the list reduction in the Alginate coated group(Figure 1).

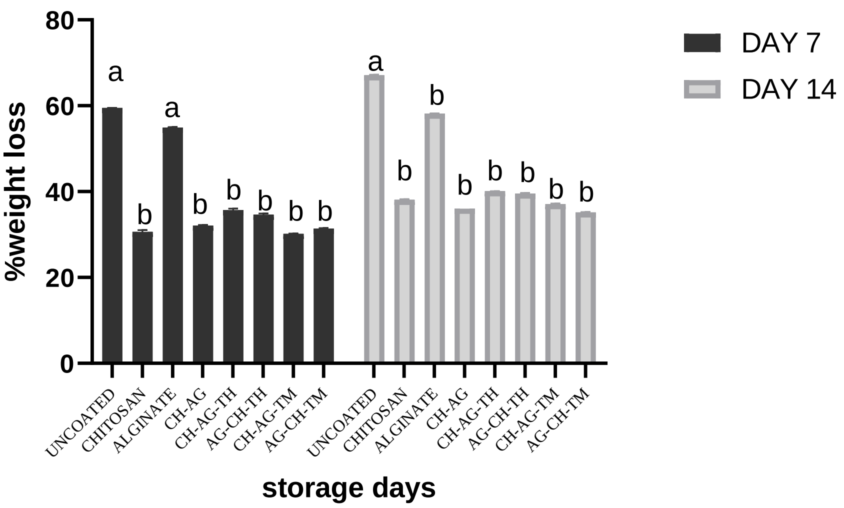

Figure 1: Comparative Physiological loss in weight of tomato (*Lycopersicon esculentum*) fruits coated with polymer complexes for 14 days. Data represent mean ± SEM for three replicates.

Polygalactorunase Activity

Polygalactrunase activity was significantly lower in the uncoated tomato fruits and those coated with all other coating polymers except AR-CH-TH and CH-AG-TM which was significantly high on the 7th day. However, on the 14th day, there was significant increase in tomatoes coated with all polymer groups except those coated with chitosan alone which was not significantly different from the uncoated group (Figure 2).

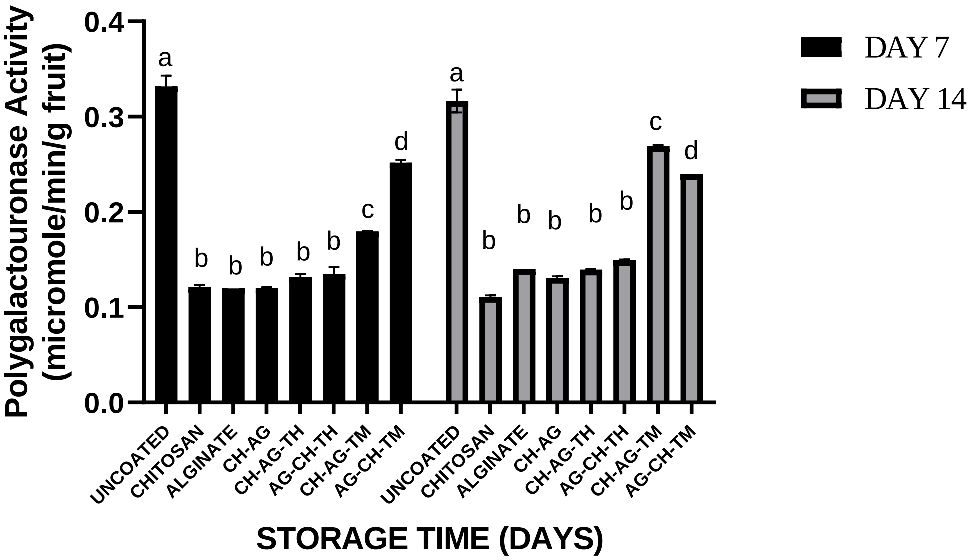

Figure 2: Comparative polygalacturonase activity in tomato (*Lycopersicon esculentum*) fruits coated with polymer complexes for 14 days.Data represent mean ± SEM for three replicates.

Polyphenol Oxidase Activity

Polyphenol oxidase activity was significantly reduced in all treatment groups with the most significant reduction in essential oils of thyme embedded in CH-AR in both 7th and 14th day (Figure 3). Polyphenol oxidase activity in fruits coated with turmeric essential oil were significantly lower than those coated with thyme essential oil.

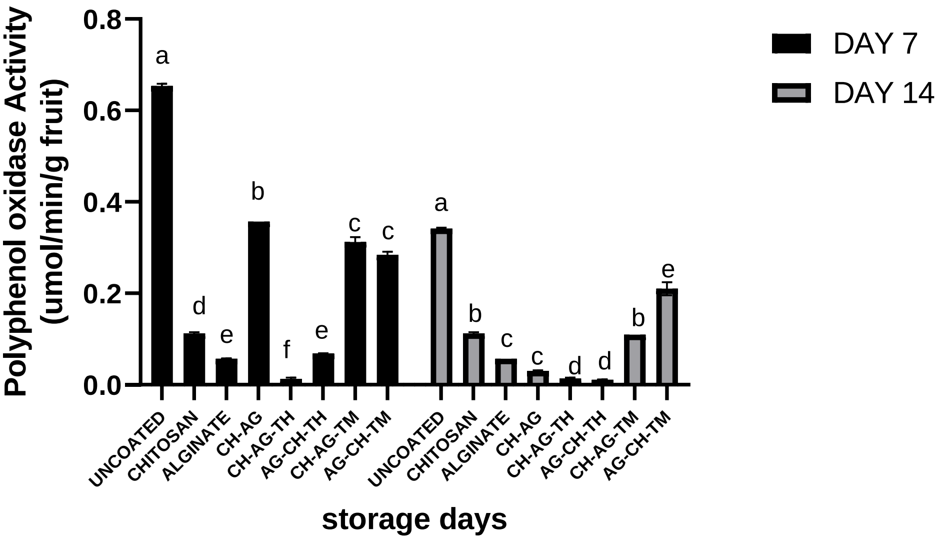

Figure 3: Comparative Polyphenol oxidase activity in tomato (*Lycopersicon esculentum*) fruits coated with polymer complexes for 14 days. Data represent mean ± SEM for three replicates.

Peroxidase Activity

Peroxidase activity significantly reduced in all treatment groups. The most significant reduction observed on day seven was in CH-AG-TH and CH-AG coated groups and subsequently on the 14th day, peroxidase activity was lowered in the thyme essential oil coated fruits than the turmeric essential oil coated group (Figure 4).

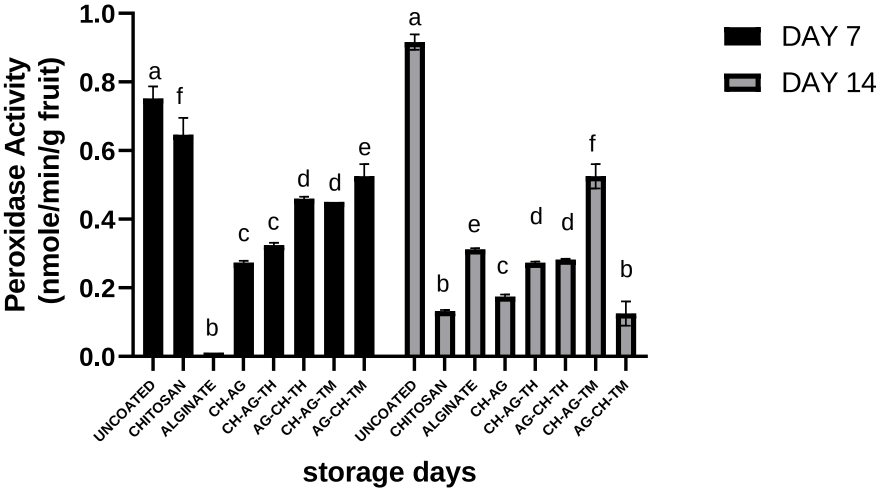

Figure 4: Comparative peroxidase activity of tomato (*Lycopersicon esculentum*) fruits coated with polymer complexes for 14 days. Data represent mean ± SEM for three replicates.

Ascorbic Acid Concentration

Ascorbic acid concentration was increased in all treatment groups on the 7th day and on the 14th day. The most significantly high ascorbic acid concentration was observed in CH-AG-TH (Figure 5).

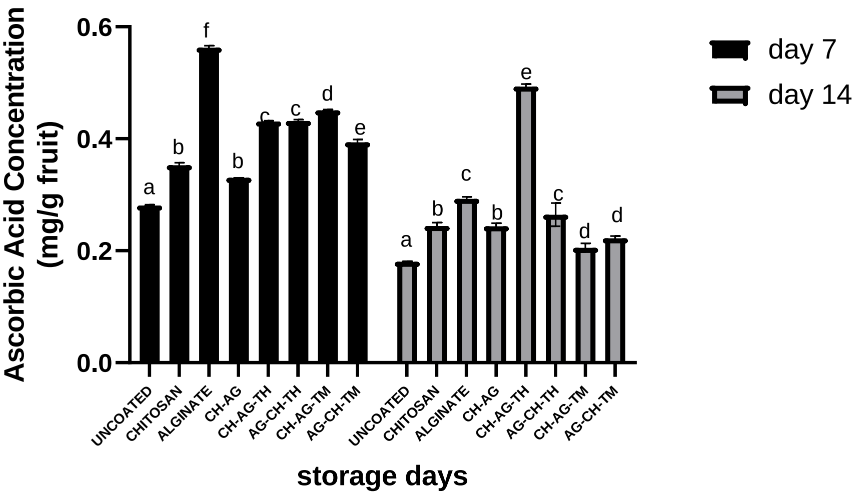

Figure 5: Ascorbic acid concentration in tomato (*Lycopersicon esculentum*) fruits coated with polymer complexes of thyme and turmeric for 14 days. Data represent mean ± SEM for three replicates.

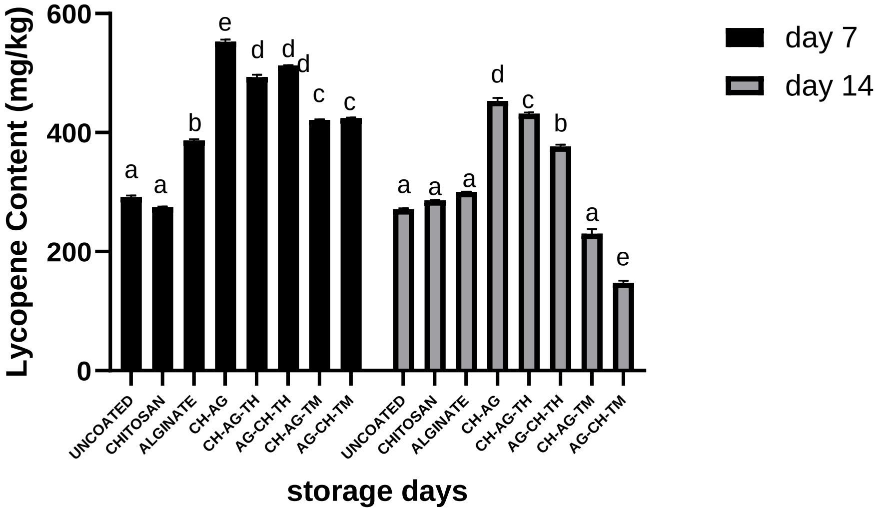

Figure 6: Comparative Lycopene content in tomato (*Lycopersicon esculentum*) fruits coated with polymer complexes of thyme and turmeric for 14 days. Data represent mean ± SEM for three replicates.

Lycopene Content

Lycopene concentration was significantly increased in all coated groups except those treated with chitosan alone on the 7th day while on the 14th day, only groups coated with CH-AG, CH-AG-TH and AR-AG-TH had significantly higher in lycopene concentration (Figure 6).

Phenolics Content

Phenolic content of all the coated fruits was significantly increased with the most significant increase observed in the groups coated with AG, CH-AG-TH and AR-CH-TH on the 7th day and on the 14th day, CH-AG-TM and AG-CH-TM has the least significant concentration of phenolic content (Figure 7).

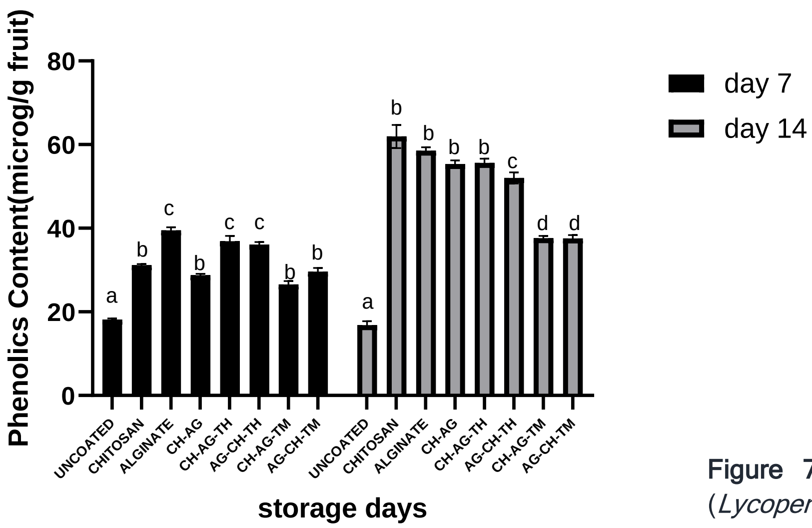

Figure 7: Comparative total phenolics in tomato (*Lycopersicon esculentum*) fruits coated with polymer complexes of thyme and turmeric for 14 days. Data represent mean ± SEM for three replicates.

Total Antioxidant Capacity

The total antioxidant capacity of the tomato fruits coated groups are all significantly higher than the uncoated fruits except the groups coated with CH-AR-TM AND AR-CH-TM both on the 7th and 14th day (Figure 8).

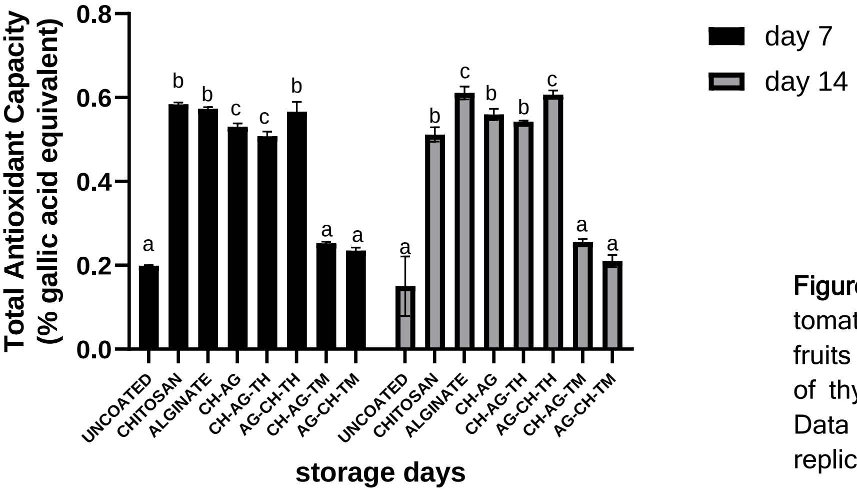

Figure 8: Total antioxidant capacity of tomato (*Lycopersicon esculentum*) fruits coated with polymer complexes of thyme and turmeric for 14 days. Data represent mean ± SEM for three replicates.

Browning Index

The relative browning index in all the treatment groups were significantly reduced with the most significant reduction observed in the group coated with CH-AG-TH. Moreover, groups coated with CH, CH-AG-TM and AG-CH-TM has the highest index of all groups after the uncoated groups (Figure 9).

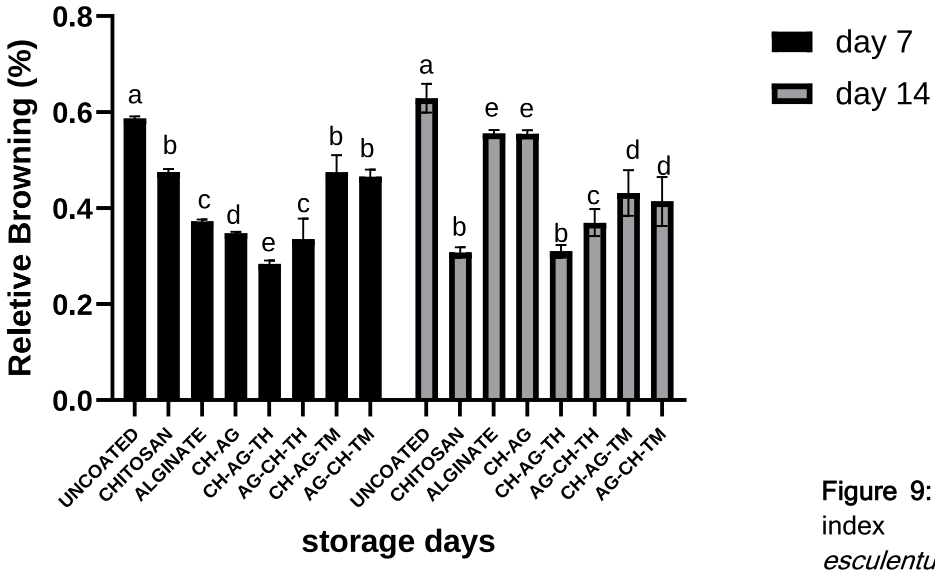

Figure 9: Comparative relative browning index of tomato (*Lycopersicon esculentum*) fruits coated with polymer complexes of thyme and turmeric for 14 days. Data represent mean ± SEM for three replicates.

Discussion

Physicochemical and physiological changes occurring during ripening and maturation of tomato fruits are part of the factors that contributes to loss of physiological weight during the post-harvest period (Tolasa *et al.*, 2021). Ability to retain the moisture content and hence the physiological weight is one of the main factors that influence the fruit's sensory quality, preservation of nutrients and nutritional values (Correira *et al*, 2017). Generally, the percentage physiological weight loss increases in tomato fruit as the storage days increases. This may be as a result of physiological processes and responses to the atmospheric conditions within treated and untreated tomato fruits as weight loss of most fruits and vegetables during storage depend on the temperature and relative humidity conditions (Pérez *et al.*, 2016).

However, comparatively in this study, the percentage loss was less in all the coated groups as compared to the uncoated fruits. According to Mohammed *et al.* (1999), transpiration is a major factor leading to the deterioration in fruits as it results in direct quantitative loss (loss of weight) which is the principal cause of fruit softening and shriveling and hence loss of fresh appearance (Acedo, 1997). Reduction in the % weight loss by coatings may be as a result of the covering of the stomata and lenticels of the cell wall of the fruits. Hence reducing the rate of transpiration and respiration (Zewdie *et al.,* 2022).

Polygalacturonase together with polyphenol oxidase synergistically to the depolymerization of cell wall pectin chains (Fachin *et al.* 2003) which is the component of the tomato cell that keeps it firm. Hence, decreased activity of polygalaturonase and polyphenol oxidase will prolong the period of durability of the tomato cell wall and quality. Activity of polyphenol oxidase also produces various types of colored pigments, which cause enzymatic browning or color changes in fruits (Ghafoor and Choi, 2012). Hence, in this comparative study, polymers of thyme essential oil was able to reduce the activities of these duo enzymes and thus the resultant reduction in the browing index observed more than the relative effect of turmeric essential oil complexes.

Peroxidase is a group of enzymes that catalyze the reduction of peroxides and oxidation of organic compounds (Koksal, 2011). They are capable of food spoilage under low temperature (less than zero) and moisture level. They are responsible for enzymatic browning of fruits (Yu *et al.*, 2017) which rarely happen in intact fruits. However, enzymatic browning commonly occurs at cut surfaces of fruits leading to rapid change of colour of the cut surface(s) due to the oxidation of phenols to orthoquines which in turn quickly polymerize to form brown pigment or melanins (Jiang *et al.*, 2004).

Thyme essential oil complexes has significantly lowered peroxidase activity than does turmeric essential oils. In the current study, ascorbic acid concentration in the tomato fruits coated increase with increasing days of study and later reduced with most significant reduction in the groups coated with CH-AR-TM and AR-CH-TM. Thyme essential oil (CH-AR-TH and AR-CH-TH) had the highest concentration of ascorbic acid with the alginate coated group. This is in alignment with Tigist *et al.* (2013) and Jamir and Khawlhring (2017) that ascorbic acid content increases with increasing days of ripening until the peak is reached and then declines. This result trend is in line with other research of Ali *et al*. (2010). It also reveals that thyme essential oil coating is more potent in retaining the ascorbic acid content in the tomato fruit than the turmeric essential oil. Presence of high ascorbic acid content can also reduce the browning (Soliva-Fortuny and Martin-Belloso, 2003). Hence, the preservative appearances observed in this study.

Conclusion and Recommendations

In conclusion, thyme essential oil embedded in chitosan arginate complex is better for the preservation of tomato fruits than the turmeric essential oil-based coatings. It is recommended that further research should be done on the commercial utilization of this complex for edible fruit preservation. Its toxicity evaluation also needs to be done.

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