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Efficacy of Gum Arabic as an esculent film on shelf life extension of tomato (*Solanum lycopersicum* L*)* fruit

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Abstract Effect of Gum Arabic (GA) as a non-toxic outer layer to prolong the shelf-life of tomato was carried out in the present study. Tomatoes were coated with 0% (Control) (A), 5% w/v (B), 10% w/v (C), 15% w/v (D) and 20% w/v (E) GA and stored at ambient (33°C; 70%). The polygalacturonase and β-galacturonase activities were carried out. Weight loss, titratable acidity, pH, lycopene, β-Carotene and antioxidant property of the fruits were determined at day 0, 5, 10, 15 and 20 during the experimental duration. Results indicated that polygalacturonase activity ranged from 0.753-1.138 unit/mg, β-galacturonase activity ranged from 1.55-2.78 x 10^3 miller units, β-carotene ranged from 1.78-23.89 mg/g, antioxidant property ranged from 66.26-192.12µg/g, titratable acidity was from 0.595-0.95% while the lycopene ranged from 0.77-17.62 mg/g. These results showed that control had significant rapid weight loss with faster rate of softening while the tomatoes coated with GA demonstrated a significant ($p<0.05$) deferment in ripening as well as maintained its nutritional quality up to 20 days. This indicates that GA may be utilized as an edible coating for tomato.

Key words: Edible film, Gum Arabic, ripening, shelf life.

1 Introduction

The process of gas exchange continues in fresh fruits and vegetables even when they have been harvested and are thus extremely short-lived and vulnerable to various diseased conditions (Chien *et al.* 2007). Swift maturity and senescence which promotes desiccation or water loss is as a result of continuous respiratory activity which in turn leads to quality loss of the produce (Maftoonazard *et al.* 2008). Tomato originated from elevated region of Peru and Ecuador, and it is usually cultivated in mild weather conditions. It ranks next to potato and sweet potato with respect to world vegetable

production. It is widely cultivated in tropical, subtropical and temperate climates, and thus ranks third in terms of world vegetable production (Gebisa *et al*. 2016). The appearance of a good fruit must have a hard, uniform and shiny colour, and no signs of mechanical damage, shriveling, or rot. Principal causes for postharvest losses are decay, external damage encountered during harvest and handling at an inappropriate stage (Sargent and Moretti 2002). During the early phase of ripening, tomatoes are responsive to chilling injury thus the use of low temperature for preservation is not encouraged (Harold *et al.* 2007). It is usually advised to harvest tomato fruits at mature green phase to reduce damage during post-harvest handling. The major loss of tomatoes occurr as a result of deterioration during handling and distribution, and this damage is intense when they are at the breaker and progressive stage of ripeness (Moneruzzaman *et al*. 2008).

Edible food packaging is of major interest. The increasing concern and inquiry in edible packaging have been motivated by the current awareness of the unfavourable effect of non-decomposable packaging waste and the rise in consumer preference for secure, simple and consistent food (Krochta 2002).

Gum Arabic is an anhydrous discharge from the stalk and shoot of Acacia senegal trees which is grown in Sudan as a cash crop. Gum Arabic is known globally in the comestible, beverage and pharmaceutical sector as a competent supplement to produce a stable system, film building and an outer layer/ encapsulating agent, oxidation inhibitor, stabilizer, emulsifier, texturant, clouding, clarifying agents and food adhesive (Murwan *et al*. 2008). Gum Arabic evolves and exists within the confine of the ecosystem, and is made up of carbohydrate characterized with high affinity for water and water hating protein components (FAO 1990). The hydrophobic protein function in keeping an emulsion from separating by accumulating on a surface of oil droplets while the water loving carbohydrate component prevents suspension of particle in a liquid and merging of two molecules (Anderson and Weiping 1990).

The development of edible coating produced from two composites, such as polysaccharides, proteins and/or lipids increasing the functionality of the coating has received attention in a recent review (Hassan *et al*. 2018). This is because each coating material has unique but limited functions. Polymers such as polysaccharides and protein, which are hydrophilic in nature are excellent thin layer mold with good flavour and serve as obstacles to lipids at low relative humidity. However, they cannot act as barriers to water. These materials are better gas barriers rather than preventing moisture loss. Nevertheless, some polysaccharides can retard moisture loss by serving as molecules to be destroyed rather than moisture barrier (Kester and Fennema 1986). Films made from proteins are fragile and can easily break due to its strong conformity, hence, the addition of a material that can interact cohesively with protein makes it more flexible (Sothornvit and Krochta 2005). Protein film is also a poor moisture barrier like a polysaccharide film (Lin and

Zhao 2007). Ali *et al*. (2010) observed that, in banana, Gum Arabic has not shown any antifungal activity against *Colletotrichum musae* (the causal agent of anthracnose) but mixture of coatings produced from Gum Arabic with chitosan showed remarkable antifungal effects compared to only chitosan. A study by Ali *et al*. (2013) explained the operation of a new coating produced from Gum Arabic on tomato fruits, it was observed that compared to uncoated fruits, tomatoes coated with 10% Gum Arabic presented significantly lower rates of changes in weight, colour, firmness, titratable acidity, soluble solids content, ascorbic acid content, and decay percentage.

The aim of the present research is therefore to formulate comestible film with Gum Arabic which is readily available and cost effective (in Nigeria) to prolong the shelf life of tomato fruit, and to monitor the activity of the softening enzymes and nutritional qualities of the tomato fruit during storage.

2 Materials and methods

2.1 Reagents

All reagents used were of analytical grade, and most of them were products of SIGMA-ALDRICH, Germany and BDH, England.

2.2 Plant materials

Fresh tomato (Abindi kerewa *var*.) was harvested from a farm within University of Ilorin campus, Ilorin, Nigeria and was transported in stackable plastic crates to the Chemistry/ Biochemistry Laboratory of Nigerian Stored Products Research Institute (NSPRI) Headquarters, Ilorin, Nigeria. The sample was identified and mature green tomato with trace of yellow according to the USDA Standard Tomato Colour Classification Chart (USDA, 1991) and of consistent size with no insect damage were used in the present study. Tomatoes were grouped into five, and placed separately in storage cartons. The initial weight of each group was noted. Group A was the control while groups B, C, D and E were coated with 5%, 10%, 15% and 20% (w/v) Gum Arabic (Loba Chemie, India) respectively.

2.3 Production of Gum Arabic (GA) solution and treatment of sample with coating

Ali *et al* (2013b) method was adopted for the preparation of GA with little adjustment. GA solutions of 5%, 10%, 15% and 20% were prepared by melting 5 g, 10 g, 15 g and 20 g of its pulverized form in 100 ml of distilled

water. The mixtures were agitated with low heat (40°C) for 60 min using a magnetic stirrer/hot plate. Glycerol monostearate (1.0%) (Fisher chemicals) was annexed as a plasticizer after cooling to 30°C in order to enhance the potency and elasticity of the coating mixtures. 1M NaOH was used to adjust the pH of the mixture to 5.8. The tomatoes in five different groups were subjected to five distinctive treatments, and each treatment was administered in triplicate. Fruits were soaked in each concentration of GA solution for 1-2 min and assuring a uniform and consistent coating of the whole surface. The control fruits were immersed in distilled water. The fruits were then air-dried, loaded in storage carton, and stocked at ambient temperature (33°C) at 70–80% relative humidity. The data were collected before treatment (day 0) and at 5 day intervals for 20 days.

2.4 Enzymatic assay of polygalacturonase

The enzymatic assay of polygalacturonase was done following the method explained by Somogyi (1952).

PRINCIPLE:

$$\text{Polygalacturonic Acid} + \text{Water} \rightarrow \text{Reducing sugars}$$

CALCULATIONS:

$$\frac{\text{Units}}{\text{ml}}\text{enzyme} = \frac{(\mu\text{moles of D}-\text{Galacturonic Acid released})(\text{df})}{(10)(0.1)}$$

df = Dilution factor
10 = Time of assay (in minutes) as per the Unit Definition
0.1 = Volume (in milliliters) of enzyme used

2.5 Determination of β-Galactosidase activity

This was carried out according to Miller method (1972). The level of β-galactosidase enzyme was calculated in Miller Units as:

$$\text{Abs at } 420 \;/\; \text{Abs}600 \text{ x volume}(0.06\text{ml})\text{x reaction time}$$

2.6 Estimation of β-carotene and lycopene

β-Carotene was estimated using the dried methanol extract following Kumar *et al.* (2001) method. A volume of 10 ml of acetone-hexane mixture (4:6) was used to extract 100 mg of sample for 1 min and filtered using Whatman filter paper No 1. The absorbance was recorded using UV-Vis spectrophotometer

(SEARCHTECH, England) at three different wavelengths (453, 505 and 663 nm). The lycopene content was estimated by:

$$\beta - \text{Carotene } \left(\frac{\text{mg}}{100\text{ml}}\right) = 0.216\ x\ A663 - 0.304\ x\ A505 + 0.452\ x\ A453$$

$$\text{Lycopene } \left(\frac{\text{mg}}{100\text{ml}}\right) = -0.0458\ x\ A663 + 0.372 x A505 - 0.0806\ x\ A453$$

2.7 Extraction for antioxidant and total phenolics determination

Norsyamimi *et al.* (2014) method was adopted for the extraction with little modification. Drying of tomato was done using hot-air oven (DRYING OVEN SEARCHTECH, England) at 40°C and then pulverized using hammer mill (POLYMIX® Switzerland). The dried and pulverized samples (10 g) were extracted in 90% methanol solvent at ambient temperature (33°C) and it was left to stand for 24 hrs, the solutions were sifted using Whatman filter paper No 1. The filtrate collected was left to evaporate to produce a thick mass. The extracts were stored at 0-4°C for subsequent analyses.

2.8 Estimation of antioxidant capacity in terms of Ferric reducing antioxidant property

The ferric reducing antioxidant capacity was determined by the method explained by Ali *et al*. 2013b. A mixture of 40 µL of tomato fruit extract and 3 mL of FRAP reagent (Sigma-Aldrich) was prepared. The resulting solution was incubated for 4 min at 37 °C. Absorbance was recorded with UV-Vis spectrophotometer (SEARCHTECH England) at 593 nm, and the outcome were given as the concentration of antioxidants having a ferric reducing action equivalent to 1 mg^{-1} g $FeSO_4$ of fresh weight of fruit sample.

2.9 Determination of total phenolic contents

Makkar *et al.* (1997) method was used for the determination of total phenolic content. Portions of the tomato extract in a test tube were filled to the volume of 1 ml with distilled water. 2.5 ml of $NaCO_3$ solution (20%) and 0.5ml of Folin-Ciocalteu reagent (Loba Chemie, India) (1:1 with water) were added sequentially to the test tube, the resulting solution was shaken and the tubes were positioned away from light for 40 min, and the absorbance using UV-Vis spectrophotometer (SEARCHTECH. England) was taken at 725 nm against the reagent blank. A standard curve was plotted using gallic

monohydrate and the total phenolic content was estimated and expressed as gallic acid equivalent in mg/g of extract.

2.10 Determination of pH

Sharoba (2009) method was used to determine the pH with little modification as follows; 10 g of sample was homogenized and centrifuged (CENTURION SCIENTIFIC LIMITED United Kingdom) (5000g, for 20 min), at 4°C. The supernatant was recovered for pH measurement. The pH was measured at 20 °C with a pH meter (SEARCHTECH PHS-3C England).

2.11 Determination of titratable acidity

AOAC (2002) method was used to estimate titratable acidity. A volume of 25 cm^3 of distilled water was added to 10 g of the sample and the mixture was agitated. Whatman (No. 1) filter paper was used to filter the mixture, and 10 ml of filtrate was taken into a conical flask, and two drops of phenolphthalein added as indicator. Titration of the solution was done against 0.1M NaOH until the colour changes to pink. Titratable acidity was represented as percentage citric acid,

$$\%T.A. = V\ X\ M\ X\ F$$

where V= volume of 0.1 M NaOH used, M= molarity of NaOH, and F= factor of citric acid (0.064).

2.12 Determination of weight loss

The change in weight was monitored for each group during the storage period with the use of top loading balance (SNOWREX ELECTRONIC SCALE, LONDON). This was done by checking the weight of tomato fruits before taking samples for analyses.

2.13 Statistical Analysis

The experiments were arranged in Completely Randomized Design (CRD) with three replicates, data were subjected to analysis of variance (ANOVA), and tested for significance among treatments by Duncan's Multiple Range Test (DMRT) at ($p<0.05$) using SPSS version 21.

3. Results and Discussion

3.1 Polygalacturonase activity

Effect of Gum Arabic (GA) on the polygalacturonase activity of tomatoes is as illustrated in Figure 1. The enzyme level increased in the control and all the treated groups till day 15, however at day 20, group E (20% GA) showed the highest enzyme level of 1.138 unit/mg followed by group A (control) which was 1.052 unit/mg with groups B and D being 0.866 unit/mg and 0.929 unit/mg respectively while group C showed the lowest level of the enzyme (0.753 unit/mg).

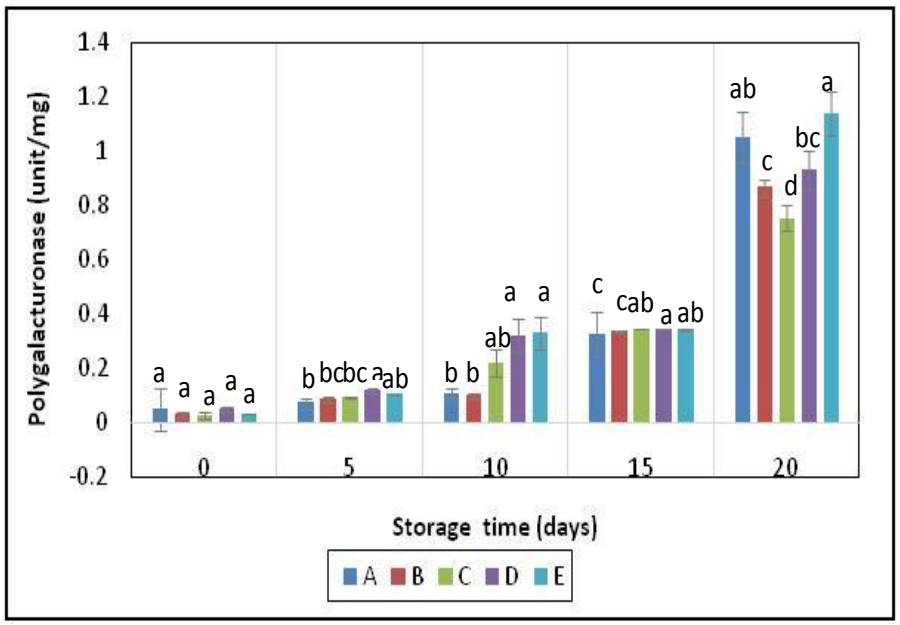

Fig. 1. Effect of Gum Arabic (GA) treatment on polygalacturonase activity of each treatment during the storage period. Bars represent means of triplicate readings (n=3). Bars with shared alphabet are not significantly different ($p<0.05$). Error bars represent standard error (SE) of the mean. A= Control (0% GA); B= 5% GA; C=10% GA; D=15% GA; E=20% GA.

The polygalacturonase [PG; poly (1,4-α-D-galacturonide) glycanhydrolase; EC 3.2.1.15] is specific in tomato only during the ripening stage of fruit maturity. PG plays an essential role in cell wall breakdown, becomes bulky during ripening, and has a role in fruit softening too (Raymond *et al*. 1988). There were significant differences between group A and C ($p<0.05$) at day 20 while there was no significant difference between groups B and D ($p>0.05$). There was also no significant difference ($p>0.05$) between groups A and E.

The higher enzyme level recorded in group A and E might be due to loss of fruit firmness as a result of increase hydration of cell wall occasioned by modification of pectin rich middle lamella. The changes in the arrangement of pectin gel govern the loosening of the gel, and the cell can separate from one another (Alexander and Grierson 2002). Raymond *et al.* (1988) reported similar results where they affirmed that polygalacturonase activity increased during ripening and perform an essential role in cell wall degeneration and fruit softening. Earlier report by Anurag *et al.* (2009) also stated that the polygalacturonase enzyme level increases as fruit ripens as observed in the present study.

3.2 β-Galactosidase activity

The level of β-Galactosidase activity of tomatoes coated with GA is shown in Figure 2. The level of β-Galactosidase increased in all the test groups. In group A, the enzyme increased from 1.54-2.78 x 10^3 miller units, for group B, it increased from 1.53-2.69 x 10^3 miller units, group C increased from 1.55-2.59 x 10^3 miller units, group D increased from 1.57-2.782 x 10^3 miller units while group E increased from 1.58-2.75 x 10^3 miller units during the storage period. There was no significance difference ($p>0.05$) in the enzyme level at day 20.

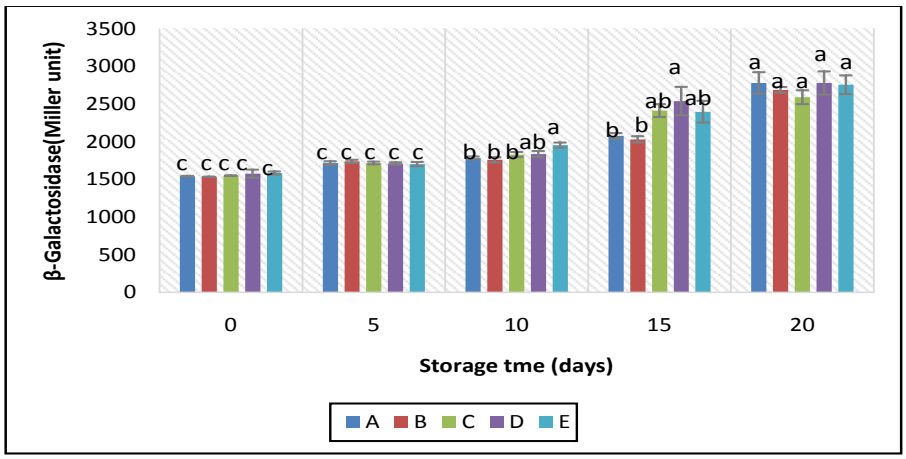

Fig. 2. Effect of Gum Arabic (GA) treatment on β-galactosidase activity of each treatment during the storage period. Bars represent means of triplicate readings (n=3). Bars with shared alphabet are not significantly different ($p<0.05$). Error bars represent standard error (SE) of the mean. A= Control (0% GA); B= 5% GA; C=10% GA; D=15% GA; E=20% GA.

In group A, there was an increase in the enzyme level up to day 15, however at day 20, the level of the enzyme increased rapidly with group C showing lowest level of the enzyme indicating that the fruits in this group retain its firmness. Anowar *et al.* (2014) reported that β-Galactosidase could be an important enzyme mainly accredited for cell wall alteration and changes in fruit during ripening as it is known to be a glycosidase that acts on short chain oligomers of galactose residues present either as homo- / hetero poly-saccharides, glycoproteins, or glycolipid. β-Galactosidase activity increased in all the groups as the activity of the enzyme is seen in all the groups; however the lowest activity recorded in group C might be as a result of the reduction of cell wall modification. As observed in the present study similar findings were reported by Emmadeldin *et al.* (2012) where they reported that β-Galactosidase plays a major role in fruit softening.

3.3 Changes in the β-Carotene content

The effect of GA coating on β-Carotene content present in each group during the storage period is shown in Figure 3. β-Carotene content in group A (control) increased from 1.78 mg/g at day 5 to 21.79 mg/g at day 15 after which it dropped sharply to 3.54 mg/g at day 20. In all the treated groups (B, C, D and E) the β-Carotene content also increased up to day 15 and decreased at day 20. Group B (5% GA) showed the highest β-Carotene content of 23.89 mg/g at day 15 while group E (20%) showed the lowest β- Carotene content of 14.47 mg/g at day 15.

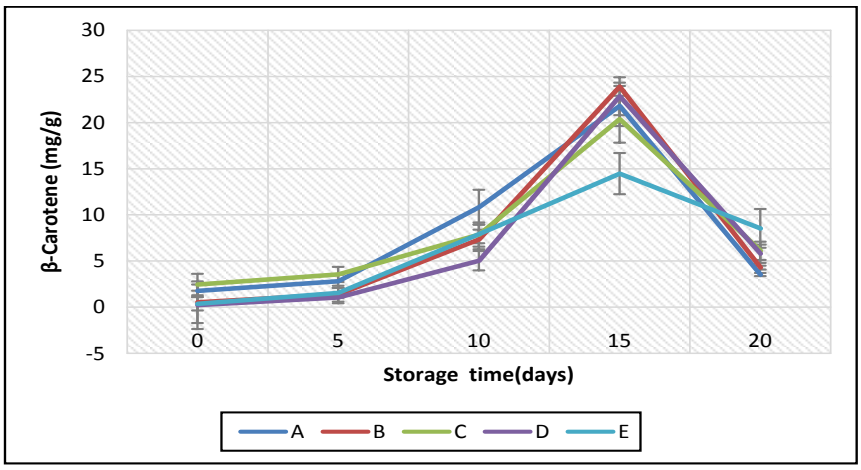

Fig. 3. Effect of Gum Arabic (GA) treatment on β-Carotene content of each treatment during the storage period. Bars represent means of triplicate readings (n=3). Bars with shared alphabet are not significantly different ($p<0.05$). Error bars represent standard error (SE) of the mean. A= Control (0% GA); B= 5% GA; C= 10% GA; D= 15% GA; E= 20% GA.

The pro-vitamin A activity of β-carotene is of special interest. The inadequate retinol supply in notable parts of the world is being balanced by β-carotene intake (Tilman *et al.* 2010). There was a significant difference ($p<0.05$) between group B (5%) and E (20%) at day 15 while there were no significant differences ($p>0.05$) among groups A, B, C and D. The sharp increase in β-Carotene content in group A might be due to ripening of the tomato fruit compared to group D and E. The result is similar to what was reported by Meredith and Young in (1971) where β-Carotene content in tomatoes decreased as it reaches the peak of ripening stage. Ali *et al.* (2013) also reported similar results where β-Carotene increased in the control up to 8 days; however the change in the current study may be connected with geographical location.

3.4 Changes in the lycopene content

The effect of GA treatment on the lycopene contents of treated tomato are illustrated in Figure 4. The lycopene content increased in the control and the treated groups. The lycopene content in group A (control) increased from 0.77 mg/g at day 0 to 15.69 mg/g at day 15 and the group B reached peak of 16.33 mg/g at day 15. The group C had the highest lycopene content of 17.62 mg/g at day 15 which dropped sharply at day 20. The lycopene content of group D and group E were comparably low to those of groups A, B and C at day 15.

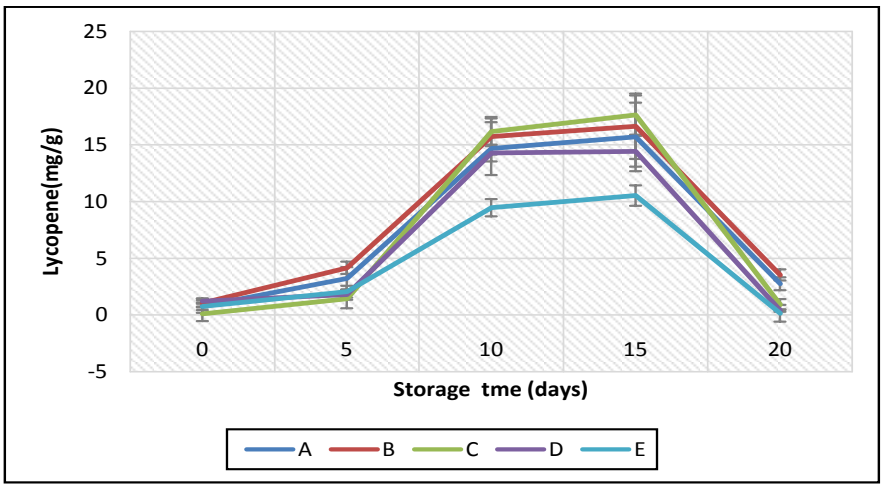

Fig. 4. Effect of Gum Arabic (GA) treatment on Lycopene content of each treatment during the storage period. Bars represent means of triplicate readings (n=3). Bars with shared alphabet are not significantly different ($p<0.05$). Error bars represent standard error (SE) of the mean. A= Control (0% GA); B= 5% GA; C=10% GA; D=15% GA; E=20% GA.

Compared to other carotenoids, lycopene had a very potent antioxidant activity and demonstrate the strongest physical quenching rate constant with reactive oxygen species (Abdul-Hammed *et al*. 2015). There were no significant differences ($p>0.05$) in lycopene content of the groups A, B, C and D while group E showed a significant difference ($p<0.05$) at day 15. Lycopene content increased as fruit matures (Gil-Randez *et al.* 1998). The initial increase in lycopene content as storage days increased might be due to increased respiratory rate of fruit which in turn increased the breakdown of lycopene due to cellular breakdown thereby resulting in a decrease in lycopene content towards the end of the experiment. The immediate increase in the lycopene content in groups A, B and C may be due to ripening of the fruit compared to those groups treated with higher concentration. Ali *et al.* (2013) reported similar results when increase in lycopene content was attributed to faster ripening. Abdul-Hammed *et al.*(2015) also reported similar results where the concentrations of lycopene, the ripening and antioxidant index of tomatoes becomes abundant from the breaker stage to the light red and the decrease when fully red.

3.5 Change in the Antioxidant properties

The effect of GA coating on the antioxidant capacity determined in terms of FRAP (Ferric Reducing Antioxidant Power) of tomatoes is shown in Figure 5.

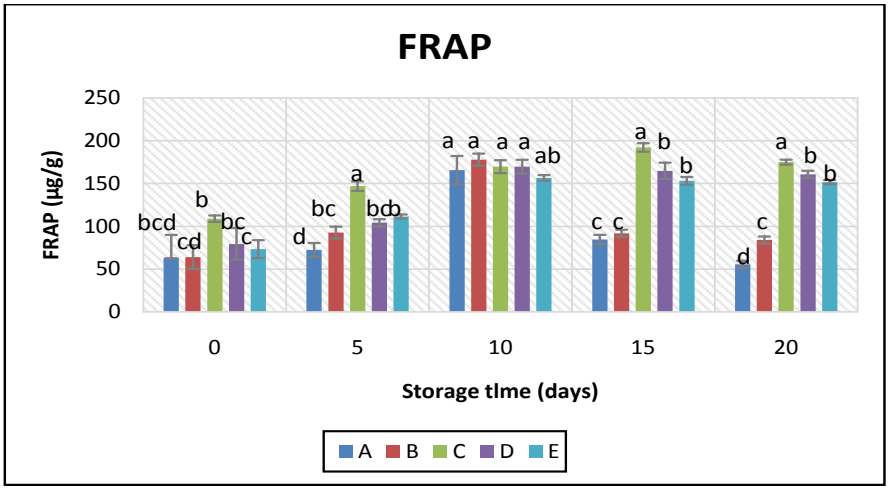

Fig. 5. Effect of Gum Arabic (GA) treatment on the antioxidant property of each treatment during the storage period. Bars represent means of triplicate readings (n=3). Bars with shared alphabet are not significantly different ($p<0.05$). Error bars represent standard error (SE) of the mean. A= Control (0% GA); B= 5% GA; C=10% GA; D=15% GA; E=20% GA.

Group A (Control) showed the highest antioxidant capacity of 165.59 µg/g at day 10 and dropped at day 15 and 20 to 84.62 µg/g and 55.50 µg/g respectively. Groups B and C also showed the highest antioxidant capacities at day 10 and 15 respectively while groups D and E showed highest antioxidant capacity at day 10. Group C compared to others showed highest antioxidant capacity of 192.12 µg/g at day 15.

The advantage of consuming fruit and vegetables cannot be ascribed to a lone compound but to the stimulating and additive effects between different phytochemicals. Free radicals scavenging abilities in fresh fruits and vegetables rely on several factors such as species, cultivars, environmental conditions, geographical origin and analytical methods (Chun *et al.* 2005). There was a significant difference ($p<0.05$) among group C, D and E while groups A and B showed no significant difference ($p>0.05$) at day 15. Also groups D and E showed no significant difference ($p>0.05$). There is usually a correlation between the antioxidant activity with the total phenolic and flavonoid contents (Tehrani *et al.* 2011). This corresponding characteristic is an indication that phenolics and flavone compounds are possibly the main compound responsible for the high antioxidant in fruits (Stratil *et al.* 2007). Reyes and Cisneros-Zevallos (2003) also reported corresponding characteristics between total phenolics and total antioxidant activity. Similar result was reported by Bhandari and Lee (2016) where antioxidant capacity increase to a certain ripening stage in some cultivars of tomato and later decreased.

3.6 Change in the total phenolics content

The change in the total phenolic contents in all the groups of tomatoes as affected by GA treatment are shown in Figure 6. The total phenolic contents increased in group A from 227.44 µg/kg to 3563.00 µg/kg at day 15 and thereafter decreased to 1101.89 µg/kg at day 20. Also in the treated groups (B, C, D, E) the total phenolic contents also increased up to day 15 and decreased at day 20. Although the highest phenolic content was reached in all the groups on day 15, the group C (10% G.A) showed the highest phenolics at 3825.73 µg/kg. The total phenolic contents reduced at day 20 in all the groups with the group A being the lowest at 1101.89 µg/kg.

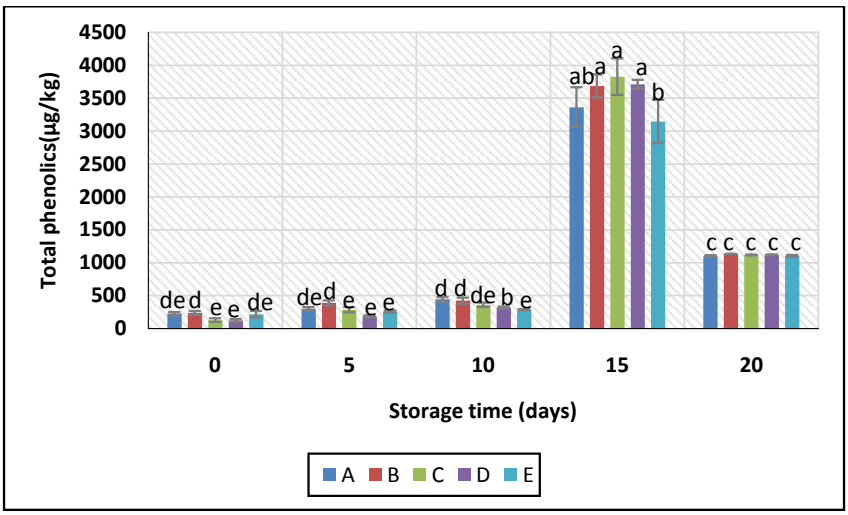

Fig. 6. Effect of (Gum Arabic) GA treatment on total phenolics content of each treatment during the storage period. Bars represent means of triplicate readings (n=3). Bars with shared alphabet are not significantly different ($p<0.05$). Error bars represent standard error (SE) of the mean. A= Control (0% GA); B= 5% GA; C=10% GA; D=15% GA; E=20% GA.; D=15% GA; E=20% GA.

The health promoting effects of fruits and vegetables is attributed to phenolic compounds; essential secondary plant metabolites, the most important of which is the antioxidant activity associated with diminished danger of cancer and cardiovascular diseases. Phenolic compounds contribute about 60–70% of the ability to prevent oxidation of other chemicals of tomato extracts (Bhandari and Lee 2016). There was no significant difference ($p>0.05$) among the groups at day 20. The maximum total phenolic content shown in group C (10% GA) is an indication that the group retained higher amount of antioxidant than the other groups. The effect of ethylene, a phytohormone which simulate the activity of phenylalanine ammonium lyase (PAL) an important enzyme in phenol biosynthesis could result in increase in phenol content during ripening (Anne and Michaela 2009). The senescence and breakdown of cell structure during storage might results in the reduction in total phenolics content recorded towards the end of the experiment in all the groups (Macheix *et al.* 1990). Similar results were reported by Ghasemnezhad *et al.* (2010) and Ali *et al.* (2010), where a decrease in total phenolics was recorded at higher concentration of chitosan.

3.7 Change in titratable acidity

The effect of GA titratable acidity values of tomatoes are as illustrated in Figure 7. Titratable acidity values increased in all the groups up to 15 days of

storage with fruits in group C showing highest value of 0.95g/ml at day 15. The titratable acidity thereafter decreased in all the groups with group E showing the lowest value of 0.61g/ml at day 20.

The titratable acidity of the tomato increased significantly ($p<0.05$) from 10 days of storage; this could be potentially attributed to more organic acids being produced during the storage period. In contrary, Lugwisha *et al.* (2016) reported a decrease in titratable acidity in Tanzania sugar apple fruits from 0.28 to 0.12% during ripening, which was predicted to be associated with the usage of component acids in the respiratory process.

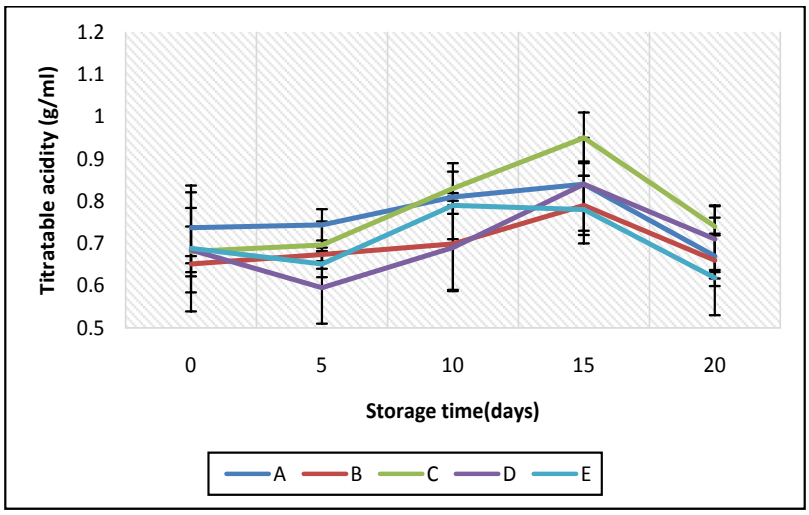

Fig. 7. Effect of Gum Arabic (GA) treatment on titratable acidity of each treatment during the storage period. Bars represent means of triplicate readings (n=3). Bars with shared alphabet are not significantly different ($p<0.05$). Error bars represent standard error (SE) of the mean. A= Control (0% GA); B= 5% GA; C=10% GA; D=15% GA; E=20% GA.

3.8 Changes in the pH value

The effect of GA treatment on pH values of tomatoes during the storage period are shown in Figure 8. The pH of group A falls within the normal range for tomato (3.7-4.5). The pH of the treated groups (B, C, D, E) also falls within the normal range of tomatoes with an exception in group E which was 4.70 at day 20.

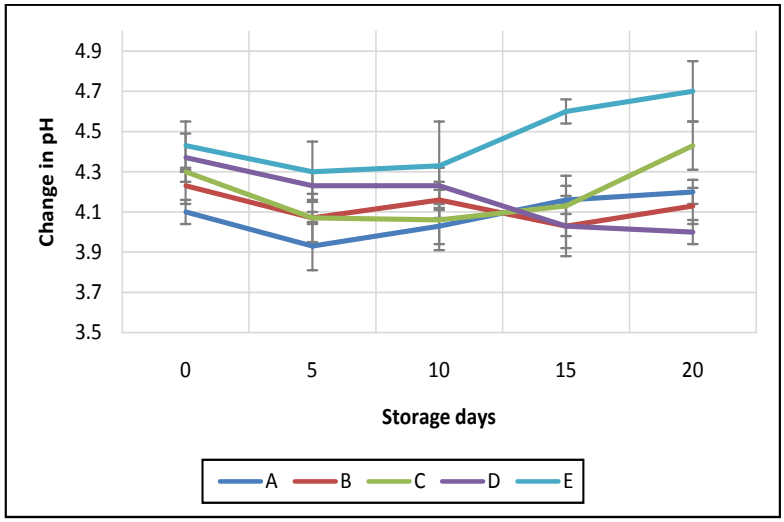

Fig. 8. Effect of Gum Arabic (GA) treatment on pH of each treatment during the storage period. Bars represent means of triplicate readings (n=3). Bars with shared alphabet are not significantly different ($p<0.05$). Error bars represent standard error (SE) of the mean. A= Control (0% GA); B= 5% GA; C=10% GA; D=15% GA; E= 20% GA.

The pH of the control and treated groups were fluctuating all through the storage period and they were all within the range acceptable for tomato (3.7-4.5), however at day 20 the pH of group E exceeded 4.5, this phenomenon could possibly be due to oxidation of acid during storage resulting in higher pH. The previous report available on the pH values of tomatoes was strengthened in this result. For instance, Mohammed *et al*. (1999) reported that though the pH of ripe tomatoes may be greater than 4.6, tomato products are widely grouped as acidic foods with the pH below 4.5 being the acceptable value as it stops microorganism breeding.

3.9 Weight changes

The effect of GA treatment on change in weight of tomato fruits in each group is presented in Table 2. The weight decrease in all the groups, for group A, the average weight reduced from 311.67 g to 275.00 g, group B reduced from 306.67 g to 272.66 g, group C also dropped from 309.67 g to 278.33 g, group reduced from 283.00 g to 246.00 g, and group E reduced from 262.67 g to 221.33 g.

Table 2. Effect of Gum Arabic (GA) on weight changes (g) of coated tomato during the storage period (all the values are mean ± SEM of triplicates. A= Control (0% GA); B= 5% GA; C=10% GA; D=15% GA; E=20% GA).

Group	Initial	Day 5	Day 10	Day 15	Day 20
A	311.67±4.33^{a}	291.67±4.09^{ab}	287.00±2.03^{c}	282.67±4.37^{b}	275.00±6.08^{b}
B	306.67±4.91^{c}	291.00±1.53^{b}	287.33±0.83^{b}	280.00±1.15^{c}	272.66±2.33^{c}
C	309.67±4.91^{b}	296.00±4.58^{a}	293.67±4.7^{a}	290.33±4.91^{a}	278.33±4.48^{a}
D	283.00±13.32^{ad}	269.33±13.38^{c}	264.00±14.19^{ad}	254.33±14.43^{ab}	246.00±13.20^{ab}
E	262.67±5.04^{ac}	253.33±4.41^{ab}	240.00±3.05^{ac}	229.33±3.18b^{c}	221.33±3.71^{ac}

Generally tomato stored at ambient condition tends to lose water which may results in loss of weight. Singh and Reddy (2006) also attributed the loss of weight to the change in soluble sugar concentration resulting from the usage of monosaccharides for respiratory purposes during storage. The loss of water from fruit is normally through diffusion from the fruit skin to the atmosphere, the extent of transpiration depends on external and environmental factors such as temperature, relative humidity, air movement and atmospheric pressure (Joyce and Patterson, 1994). The weight loss observed in this study is in agreement with the report of Singh and Reddy (2006).

4 Conclusions

Comparative analysis on the effects of several coating concentrations of Gum Arabic and storage condition on the quality and the shelf-life of tomato fruits, revealed that the group coated with 10% Gum Arabic and stored at ambient temperature was the best treatment for maintaining the quality and extending the shelf-life of tomato fruit over other treatments or control. It showed lower polygalacturonase activity, lower β-Galactosidase as well as higher lycopene and β-carotene, higher antioxidant capacity in terms of Ferric reducing antioxidant power, higher total phenolics and higher titratable acidity, reduced decay incidence. Results suggest that Gum Arabic is effective in reducing the activity of the ripening enzyme while maintaining the quality and extending the shelf-life of tomato fruit.

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