

COLOR OF DEHYDRATED TOMATO: EFFECTS OF GUM ARABIC

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The efficacy of gum arabic, as a color preservative and inhibitor of non-enzymatic browning of dehydrated tomato during storage, was studied and compared with sodium metabisulfite. Tomato homogenates were treated with 1, 2.5, 5, 7.5, and 10.0% gum arabic and 1.0% sodium metabisulfite, respectively, dehydrated, and color changes were monitored during four months of storage. Water activity decreased significantly ($P \leq 0.05$) and Brix values increased significantly ($P \leq 0.05$) in gum arabic-treated samples. pH of metabisulfite treated samples is significantly ($P \leq 0.05$) higher than that of control and gum arabic treated samples. Lightness (L^) value increased significantly ($P \leq 0.05$) with the addition of 5–10% gum arabic compared to the dehydrated control. Browning index of dehydrated tomato decreased significantly ($P \leq 0.05$) with the treatments, 1 and 2.5% Gum Arabic, 1% metabisulfite, 5, 10, and 7.5% gum arabic, respectively. Gum arabic at 5–10% (w/w) was more suppressed to browning than sodium metabisulfite. Gum arabic preserved color of dehydrated tomatoes up to 4 months of storage.*

Keywords: Gum arabic, Tomatoes, Color, Preservation, Browning, Storage, Dehydration.

INTRODUCTION

Tomato is one of the world's major food crops and is valued for its taste, flavor, appearance, and vitamins and minerals contents.^[1] Phytochemicals from tomato including lycopene are renowned for their health benefits.^[2–4] Dietary intake of lycopene and other phytochemicals from tomatoes reduces the risk of prostate cancer and cardiovascular diseases.^[5,6] However, tomato is perishable and needs to be consumed shortly after harvest or preserved for later consumption. At the time of abundance preservation, through processing, is a necessity to reduce harvest losses, add value, and ensure availability of tomato products during off-seasons.^[7] Processed tomato products, such as tomato paste, canned tomato, flakes, and powder, are widely used as a component for pizza and various vegetable and spicy dishes worldwide.^[8] Processing of tomato is achieved by several

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methods of which dehydration is the most common,^[9] particularly in developing countries where low-temperature facilities are often lacking or poorly established. However, undesirable changes in quality attributes, of which discoloration due to browning and carotenoids loss is the most common, are often encountered with dehydration and long-term storage. To avoid quality deterioration, due to dehydration and associated thermal treatments and on prolonged storage, vegetable products are subjected to several pretreatments, including sulfiting. However, health hazards associated with sulfites may lead to their restricted use.^[10–13]

Various alternatives to sulfites to preserve color and control browning of dehydrated products, including sulfated polysaccharides, carrageenans, amylose sulfate, and xylan sulfate, starch, modified starches, and honey, were introduced. However, health conscious consumers demand natural ingredients and in this respect gum arabic (GA) may be a promising candidate. GA has many applications in the food industry. It is used as a stabilizer, thickener, emulsifier, and as an anti-caking agent, however, its role as a color preservative has not been thoroughly investigated.^[14]

The present study was, therefore, set to investigate the efficacy of GA on preservation of color and inhibition of browning of dehydrated tomatoes in comparison to the conventionally used sodium metabisulfite.

METHODS

Fresh tomatoes (*Lycopersicon esculintum* var. Roma) were purchased at a local market. GA, in a fine powder form (moisture content about 15%) was obtained from Khartoum Gum Arabic Processing Co., Khartoum, Sudan. Sodium metabisulfite, ($\text{Na}_2\text{S}_2\text{O}_5$) chemical grade, was purchased from BDH Chemicals (Poole, Dorset, UK).

Samples Preparation

Tomatoes, soaked and washed with running tap water, were sorted manually. Damaged and defected fruits were discarded and firm, ripe, and meaty ones were selected. Each fruit was cut into 2–4 pieces. The cut tomatoes (ca 28 kg) were steam blanched for 5 min^[15] in a steam jacketed boiling kettle (Model TDC/2–20, Groen, USA). During and after blanching a thorough mixing and homogenization was done by a top-hand mixer and homogenizer (Model 1KA-RW15, Labsco, Friedberg, Germany). The homogenate was divided into seven samples, 4 kg each. Each sample was placed into a stainless steel bowl.

Treatments

Seven treatments were carried out as follows: control (blanched tomato only) (Treatment 1), 1% sodium metabisulfite ($\text{Na}_2\text{S}_2\text{O}_5$) (40 g $\text{Na}_2\text{S}_2\text{O}_5$ /4 kg tomato homogenate) (Treatment 2), 1% GA (40 g GA/4 kg tomato homogenate) (Treatment 3), 2.5% GA (100 g GA/4 kg) (Treatment 4), 5% GA (200 g GA/4 kg) (Treatment 5), 7.5% GA (300 g GA/4 kg) (Treatment 6), 10% GA (400 g GA/4 kg) (Treatment 7). GA, dissolved in distilled water (100–200 ml) was added to tomato homogenate (1–10% w/w) with thorough mixing using a hand-top mixer for 15–20 min. A homogenate similarly prepared and treated with sodium bisulfite (1% w/w) was included for comparison. Two samples

(60 g each) from each treatment were placed in tarred (90 mm i.d.) Petri dishes, and kept for color measurements.

Dehydration

A sample, approximately 4 kg of each of the homogenates, was placed into a stainless steel tray (30 cm × 50 cm × 5 cm) and spread with a thickness of about 12–15 mm. Dehydration was carried out by conventional air drying in a pilot small scale cabinet dryer (Labsco, Friedberg, Germany), at 80°C and about 40% relative humidity for 10–14 h. Drying, hand-sensing, texture, and general appearance were used to determine the end of the dehydration process.

Storage

The dehydrated tomato samples were each divided into sub-samples (20–30 g each), packed into six transparent polyethylene bags, and sealed with a hand electrical sealer. The sub-samples, placed in black polyethylene bags, were stored at room temperature (25–30°C) in the dark. Dehydrated samples for color measurements were placed in Petri dishes, covered, sealed with parafilm, and then wrapped in aluminum foil. Plates, as sets of duplicates, were placed in black polyethylene bags and stored at room temperature in the dark. Color measurements were undertaken, in duplicate, monthly over a period of 4 months.

Analysis of Quality Attributes

pH. The dehydrated samples were rehydrated by soaking in distilled water (5 g/100 ml distilled water) for 60 min at room temperature, then samples were blended with a Waring blender (Waring Products Division, Dynamics Corporation, USA). The pH of samples was determined in duplicate, at room temperature, with a digital pH meter (Model pH 8000-Sargent, Welch-Scientific Co., Skokie, IL, USA).

Total soluble solids (TSS). A 5-g sample from each treatment were re-hydrated in 100 ml of distilled water and homogenized. The homogenates were filtered through Whatman No. 42 filter papers in conical flasks and funnels. The TSS content (°Brix) of each of the filtrates was determined, in duplicate, as described by Srivastava^[16] using a bench top Abbe Mark II digital refractometer (Model No. 10480, Cambridge Instrument Inc., NY, USA).

Water activity (a_w). Water activity (a_w) was measured, in duplicate, according to the AOAC,^[17] with AquaLab CX2 laboratory grade water activity meter series 3TE (Decagon Devices, Inc., WA, USA) at room temperature (25°C).

Moisture content. The moisture content was determined according to AOAC.^[17] Two replicate samples (3–5 g each) from each treatment were dried at 105°C to a constant weight in an oven (Type 2716, Kotterman, Germany).

Browning index. Non-enzymatic browning of the dehydrated tomatoes was determined following the method of Baloch.^[18] Dehydrated tomato samples, 0.5 g each, placed in 50-ml polypropylene flasks were extracted for 2 h, at room temperature, with 25 mL of aqueous acetic acid (2%) on an orbital shaker (Milian, Ohio, USA). The samples were filtered through Whatman No. 42 filter papers. Absorbance of the clear filtrate was measured, in duplicate, at 420 nm against a blank of 2% aqueous acetic acid.

Color measurement. Color was measured at two points (three readings each) on the upper layer of the dehydrated tomatoes placed in Petri dishes. Color parameters of a freshly prepared blanched tomatoes homogenate, placed in Petri dishes and wrapped with transparent plastic, were concurrently measured for comparison. A tristimulus colorimeter (Minolta chromameter, model CR 200, Osaka, Japan) was used to determine L, a, and b color values.^[19] The colorimeter was calibrated against a standard white color plate (L = 96.87, a+ = 0.55, and b+ = 2.14).^[20]

Statistical Analysis

Parameters, except CIE Lab system, were measured, at least in duplicate. Values of L*, a*, and b* were measured at least six times. Statistical analysis was performed by analysis of variance (ANOVA). Means were tested for significance by the Duncan's multiple range test, at $p < 0.05$ using the SAS computing program.^[21]

RESULTS AND DISCUSSION

pH

Tomato homogenates were treated with GA and sampled before dehydration displayed a pH of 4.27–4.37 (Table 1). These values are within the range reported for fresh tomato,^[22–25] and indicated that GA caused a slight increase in the initial pH of tomato homogenate. After dehydration, at zero time, the pH decreased slightly to 4.18 for the blanched control sample. The sodium metabisulfite treated sample scored a significant increase ($P \leq 0.05$) in pH (Table 1). Samples treated with GA exhibited significant ($P \leq 0.05$) change in pH; however, it is significantly ($P \leq 0.05$) lower than that caused by metabisulfite. The increase in pH of the sulfite treated sample is consistent with that reported by Baloch^[18] and may be attributed to reactivity of sulfites and probable reaction products leading, consequently, to the observed pH increase.

Total Soluble Solids

TSS of fresh tomatoes was 6.8 °Brix (Table 2). This value is consistent with that reported for Roma hybrid.^[23] The Control (blanched) sample displayed an initial °Brix value of 6.8, which is identical with that of fresh tomatoes. The metabisulfite treated samples displayed an initial °Brix value of 7.2, which is significantly ($P \leq 0.05$) different from the control. The GA treated samples exhibited °Brix values, which increased with GA in a concentration dependent manner. The °Brix values 7.1, 7.4, 8.25, 8.3, and 8.5 for 1, 2.5, 5, 7.5, and 10% GA, respectively, are significantly ($P \leq 0.05$) different from the control and metabisulfite treated samples. The increase in °Brix value for the GA treated samples is attributable to the added solute. After 4 months of storage, °Brix value increased in all samples reaching 7.4 for the control and 7.4 for the metabisulfite treated sample. The °Brix value for the GA treated samples increased with concentration and ranged between 7.25 and 9.15 for GA. The sample treated with GA at 10% displayed the highest °Brix value, which may be attributed to loss of moisture due to cracking of the sample surface.

Table 1 pH of dehydrated tomato pretreated with gum arabic at different storage periods.

Storage period (month)	Control	1% Na ₂ S ₂ O ₅	1% Gum Arabic	2.5% Gum Arabic	5% Gum Arabic	7.5% Gum Arabic	10% Gum Arabic
Zero	4.18 ^a ± 0.020	5.32 ^a _b ± 0.10	4.37 ^a _c ± 0.030	4.35 ^a _c ± 0.030	4.30 ^a _d ± 0.005	4.42 ^a _c ± 0.005	4.32 ^a _c ± 0.020
1	4.56 ^b _a ± 0.030	5.55 ^b _b ± 0.020	4.37 ^a _c ± 0.010	4.35 ^a _c ± 0.015	4.27 ^b _d ± 0.015	4.30 ^b _d ± 0.020	4.44 ^b _e ± 0.015
2	4.16 ^b _a ± 0.030	5.37 ^a _b ± 0.030	4.34 ^a _c ± 0.010	4.37 ^a _c ± 0.025	4.37 ^c _c ± 0.020	4.28 ^b _d ± 0.015	4.23 ^c _e ± 0.025
3	4.60 ^b _a ± 0.030	5.51 ^b _b ± 0.020	4.40 ^a _c ± 0.030	4.38 ^a _c ± 0.15	4.39 ^c _c ± 0.025	4.30 ^b _d ± 0.010	4.34 ^a _d ± 0.025
4	4.40 ^c _a ± 0.020	5.51 ^b _b ± 0.005	4.48 ^b _c ± 0.010	4.50 ^b _c ± 0.020	4.15 ^d _d ± 0.015	4.48 ^c _c ± 0.010	4.56 ^c _c ± 0.035

pH of fresh tomato = 4.2 ± 0.020. Values are mean ± standard deviation. Mean values having different superscript letters in columns and subscript letters in rows differ significantly at ($P \leq 0.05$).

Table 2 Brix values of dehydrated tomato pretreated with gum arabic at different storage periods.

Storage period (month)	Control	1% Na ₂ S ₂ O ₅	1% Gum Arabic	2.5% Gum Arabic	5% Gum Arabic	7.5% Gum Arabic	10% Gum Arabic
Zero	6.80 ^a ± 0.05	7.20 ^a _b ± 0.04	7.10 ^a _b ± 0.100	7.40 ^a _c ± 0.07	8.25 ^a ± 0.04	8.30 ^a _d ± 0.06	8.50 ^a ± 0.06
1	7.15 ^b _a ± 0.05	6.85 ^b _b ± 0.05	6.70 ^b _c ± 0.05	7.30 ^a _d ± 0.06	7.70 ^b _e ± 0.04	8.00 ^b _f ± 0.07	8.10 ^b _f ± 0.03
2	7.05 ^b _a ± 0.05	6.93 ^b _b ± 0.05	7.10 ^b _a ± 0.05	7.40 ^a _c ± 0.06	7.85 ^c ± 0.02	8.15 ^b _e ± 0.05	8.35 ^c _f ± 0.05
3	6.95 ^b _a ± 0.05	7.00 ^b _a ± 0.03	7.20 ^a _b ± 0.05	7.75 ^b _c ± 0.06	8.10 ^d ± 0.02	8.20 ^a _d ± 0.05	8.40 ^a ± 0.05
4	7.40 ^c _a ± 0.04	7.40 ^c _a ± 0.100	7.2 ^a _b ± 0.05	7.85 ^b _c ± 0.05	8.40 ^a _d ± 0.13	8.60 ^c _d ± 0.02	9.15 ^c _e ± 0.74

TSS of fresh tomato = 6.80 ± 0.05.

Values are mean ± standard deviation. Mean values having different superscript letters in columns and subscript letters in rows differ significantly at ($P \leq 0.05$).

Water Activity (a_w)

Table 3 shows water activity of tomato homogenate and dehydrated tomato. Fresh tomatoes displayed a water activity of 0.995, which is consistent with that reported by Lewicki et al.^[26] After dehydration (zero time), a_w was 0.328 for the control and 0.3025 for the sample treated with the metabisulfite. Samples treated with GA showed a significant ($P \leq 0.05$) decrease in a_w with increasing concentration. The inverse relation between GA concentration and a_w are attributable to the increase in solute contents of the products. During storage, all samples displayed decreased a_w values. At 4 months after storage, the control (blanched) showed an a_w value of 0.296. The a_w for the metabisulfite treated sample was 0.288. The water activity of the GA treated samples ranged between 0.3155 and 0.2745 for the lowest (1%) and the highest (10%) concentrations, respectively. A similar decrease in a_w values with storage was reported by Lewicki et al.^[26] The initial a_w values of the GA treated samples (0.253–0.4) and those recorded after 4 months of storage (0.2745 and 0.3155) are within the range reported to be conducive to maximum storage stability of many dehydrated products.^[27] It was suggested that the water molecules covering the active sites of the dry solids form a protective film that curtails oxygen diffusion and, hence, slows down the rate of chemical reactions and may thus increase storage stability.^[27]

Moisture Content

Moisture content of fresh tomatoes was 94.82%. Dehydration process at 80°C, at time zero, decreased moisture content (Table 4). The blanched control displayed a moisture content of 16.3%, which is within the reported range (10–15%).^[26,28] The sample treated with sodium metabisulfite (1%) exhibited a moisture content of 14.75%, which is significantly ($P \leq 0.05$) different from the control. Samples treated with GA displayed a significant ($P \leq 0.05$) decrease in moisture content with concentration. Samples treated with GA at 1 and 10% showed moisture content of 15.3 and 7.32%, respectively. It is probable that an increase in concentration of GA decreased the moisture content as a result of solutes addition.

During storage, all pre-treated samples displayed decreased in moisture content (Table 4). The blanched control displayed 12.4% moisture content, while the sodium metabisulfite treated sample showed moisture content of 11.82%. Samples treated with GA exhibited moisture content that consistently decreased with concentration up to 7.5%. However, at 10% GA a slight increase in moisture contents was displayed. The observed increase in moisture contents at the highest GA concentration may be due to the hygroscopic nature of the adduct leading to absorption of moisture from the surroundings, enhanced, perhaps, by some cracks of the dehydrated surface.^[29,30]

Browning Index (A_{420})

Non-enzymatic browning (NEB) is reported to account for 60–70% of the total browning of vegetables and vegetable products during storage.^[31] Fresh tomato sample displayed a low (0.0165) browning index (Table 5). Both the metabisulfite and GA treatments significantly ($P \leq 0.05$) reduced the browning index in comparison to the blanched control. The control consistently displayed the highest NEB reactions throughout the experimental period. Sodium metabisulfite reduced the browning index (BI) considerably. The

Table 3 Water activity of dehydrated tomato pretreated with gum arabic at different storage periods.

Storage period (month)	Control	1% Na ₂ S ₂ O ₅	1% Gum Arabic	2.5% Gum Arabic	5% Gum Arabic	7.5% Gum Arabic	10% Gum Arabic
0	0.328 ^a ± 0.004	0.303 ^a ± 0.005	0.400 ^a ± 0.005	0.392 ^a ± 0.0004	0.360 ^a ± 0.005	0.297 ^a ± 0.003	0.253 ^a ± 0.017
1	0.306 ^a ± 0.006	0.290 ^b ± 0.005	0.4023 ^c ± 0.004	0.380 ^b ± 0.007	0.345 ^b ± 0.005	0.310 ^b ± 0.005	0.228 ^a ± 0.002
2	0.326 ^a ± 0.006	0.288 ^b ± 0.006	0.427 ^b ± 0.007	0.402 ^b ± 0.002	0.381 ^c ± 0.005	0.354 ^c ± 0.004	0.303 ^b ± 0.003
3	0.326 ^a ± 0.004	0.288 ^b ± 0.004	0.406 ^a ± 0.006	0.384 ^a ± 0.004	0.352 ^a ± 0.002	0.339 ^d ± 0.007	0.261 ^a ± 0.004
4	0.296 ^a ± 0.004	0.288 ^b ± 0.008	0.388 ^b ± 0.006	0.363 ^c ± 0.003	0.323 ^d ± 0.003	0.303 ^a ± 0.005	0.251 ^a ± 0.005

Water activity of fresh tomato = 0.995 ± 0.005.

Values are mean ± standard deviation. Mean values having different superscript letters in columns and subscript letters in rows differ significantly at ($P \leq 0.05$).

Table 4 Moisture content of dehydrated tomato pretreated with gum arabic at different storage periods.

Storage period (month)	Control	1% Na ₂ S ₂ O ₅	1% Gum Arabic	2.5% Gum Arabic	5% Gum Arabic	7.5% Gum Arabic	10% Gum Arabic
Zero	16.3 ^a ± 0.100	14.75 ^b ± 0.025	15.30 ^a ± 0.200	12.30 ^d ± 0.100	10.40 ^a ± 0.050	7.32 ^f ± 0.040	13.05 ^a ± 0.050
1	16.00 ^b ± 0.152	14.45 ^b ± 0.025	15.00 ^a ± 0.200	12.00 ^b ± 0.100	10.10 ^b ± 0.100	7.02 ^f ± 0.020	12.74 ^b ± 0.100
2	13.83 ^a ± 0.020	13.56 ^b ± 0.040	14.50 ^b ± 0.200	12.71 ^c ± 0.030	10.68 ^c ± 0.040	6.49 ^f ± 0.030	11.76 ^c ± 0.083
3	14.30 ^d ± 0.200	15.008 ^d ± 0.040	15.66 ^c ± 0.200	12.44 ^a ± 0.040	10.92 ^d ± 0.040	7.05 ^b ± 0.30	12.79 ^b ± 0.110
4	13.94 ^e ± 0.020	12.77 ^b ± 0.030	15.48 ^c ± 0.040	12.17 ^b ± 0.030	10.68 ^c ± 0.060	7.31 ^f ± 0.100	11.86 ^c ± 0.060

Moisture content of fresh tomato = 94.82% ± 0.020.

Values are mean ± standard deviation. Mean values having different superscript letters in columns and subscript letters in rows differ significantly at ($P \leq 0.05$).

observed reduction of BI by sulfites is in line with the observation of Baloch et al.^[18] and is consistent with the high potency of sulfites as NEB inhibitors. GA pretreatments retarded NEB of dehydrated tomatoes. Subsequent to dehydration and storage, GA at 1 and 2.5% inhibited NEB, but to a lesser extent than the metabisulfite. Pretreatments with GA 5% or more were significantly ($P \leq 0.05$) superior in performance to the metabisulfite. Subsequent to dehydration, BI was 0.4425 for GA at 5% and 0.834 for the metabisulfite. Among all treatments, GA at 7.5% effected the highest inhibition of NEB and resulted in the lowest browning index throughout the experimental period. The superiority in performance of GA at 7.5% as NEB inhibitor may be attributed to absence of cracks on products' surface. Cracks observed on the product surface at the higher concentration enhanced exposure to oxygen and, consequently, oxidative deterioration and increased browning index.

The high and lasting efficacy of GA, when used at a concentration of 5% or more, in reducing deterioration and browning and in preserving color of dehydrated tomatoes in comparison to the conventional metabisulfite treatment may be due to differential stability of the products. Sulfites are highly reactive and their effectiveness as NEB inhibitors and color preservers is reported to decrease with time. Potassium metabisulfite is reported to reduce browning by 50 and 30% at 20 and 90 days of storage, respectively.^[18]

The results revealed that GA can be a good natural substitute to sulfites for controlling non-enzymatic browning (NEB) during dehydration and storage of dehydrated tomatoes. A probable explanation for GA effect on NEB is that the GA remaining on the surface layer of tomatoes prevents oxygen penetration and, consequently, curtails carotenoids, especially lycopene, oxidation. However, more subtle interactions involving the binding force of carotenoids in tomatoes' tissues cannot be ruled out. Shi et al.^[8] suggested a similar effect when sugar solutions are used in vacuum drying of tomatoes.

Redness (a+) Value

Dehydration reduced the a+ value of the control (blanched) by 22% in comparison to that recorded prior to dehydration (Table 6). The observed reduction is consistent with that reported by Zanoni et al.,^[28] but is at variance with those reported by Ramandeep and Geoffrey.^[32] The observed differences in dehydration effects may be attributed to inherent differences between the cultivars used by the different authors. During storage there was a consistent increase in a+ value of all samples (Table 6). Among all treatments, the metabisulfite treated sample displayed, significantly ($P \leq 0.05$), the highest a+ values (30.57–38.84) and showed the best red color retention.

Samples treated with GA at 1–5% displayed an a+ value comparable to the blanched control. However, GA at 7.5–10% showed a significantly ($P \leq 0.05$) higher a+ value. This finding showed that GA up to a concentration of 5% did not significantly preserve retention of the red color. Lack of significance retention of red color in these GA treatments may be due to low sensitivity of the methods.^[33] However, the possibility of increased exposure to oxygen arising from the large surface of the Petri dishes and, consequently, enhanced damage of the carotenoids cannot be ruled out.^[33]

Yellowness (b+) Value

The b+ value, an indicator of yellowness at time zero, for the control (blanched sample) was 24.54 (Table 7). This value is slightly less than the range (25.6–28.8) reported by Moraru et al.^[22] using different tomato cultivars. Dehydration decreased the b+ value to

Table 5 Browning index of dehydrated tomato pretreated with gum arabic at different storage periods.

Storage period (month)	Control	1% Na ₂ S ₂ O ₅	1% Gum Arabic	2.5% Gum Arabic	5% Gum Arabic	7.5% Gum Arabic	10% Gum Arabic
Zero	4.763 ^a ± 0.005	0.834 ^a _b ± 0.004	1.104 ^a _b ± 0.005	0.838 ^a _b ± 0.003	0.443 ^a _c ± 0.003	0.244 ^a _d ± 0.002	0.366 ^a _e ± 0.001
1	4.660 ^a _a ± 0.004	0.769 ^b _b ± 0.004	1.340 ^b _c ± 0.003	0.832 ^b _d ± 0.003	0.564 ^b _e ± 0.003	0.245 ^a _f ± 0.002	0.438 ^b _g ± 0.001
2	5.150 ^b _a ± 0.005	0.722 ^b _b ± 0.000	1.191 ^c _c ± 0.003	0.989 ^c _d ± 0.004	0.500 ^c _e ± 0.001	0.222 ^b _f ± 0.001	0.468 ^c _g ± 0.004
3	5.420 ^c _a ± 0.000	0.793 ^b _b ± 0.002	1.855 ^d _b ± 0.004	0.989 ^c _b ± 0.091	0.518 ^d _d ± 0.029	0.274 ^c _e ± 0.014	0.446 ^d _f ± 0.003
4	5.603 ^d _a ± 0.004	0.793 ^b _b ± 0.000	1.376 ^b _b ± 0.256	1.396 ^d _b ± 0.326	0.518 ^d _c ± 0.001	0.274 ^c _d ± 0.004	0.446 ^d _e ± 0.002

Browning Index of fresh tomato = 0.0165 ± 0.0005.

Values are mean ± standard deviation. Mean values having different superscript letters in columns and subscript letters in rows differ significantly at ($P \leq 0.05$).

Table 6 Redness (a+) values of dehydrated tomato pretreated with gum arabic at different storage periods.

Storage period (month)	Control	1% Na ₂ S ₂ O ₅	1% Gum Arabic	2.5% Gum Arabic	5% Gum Arabic	7.5% Gum Arabic	10% Gum Arabic
Zero	15.92 ^a _a ± 0.13	30.57 ^a _b ± 1.84	19.14 ^c _c ± 2.47	19.96 ^a _d ± 0.91	18.65 ^a _e ± 1.41	20.02 ^a _f ± 0.44	15.94 ^a _a ± 2.18
1	20.52 ^b _a ± 0.96	29.26 ^a _a ± 1.02	12.56 ^b _b ± 0.55	10.81 ^b _c ± 2.26	13.88 ^b _d ± 2.28	13.45 ^b _d ± 3.25	17.71 ^b _a ± 1.38
2	21.52 ^c _a ± 0.61	37.33 ^a _b ± 0.90	13.23 ^c _c ± 0.70	14.57 ^c _e ± 0.59	18.01 ³ _d ± 0.43	23.64 ^c _e ± 0.33	27.32 ^c _f ± 1.89
3	22.35 ^d _a ± 0.77	8.84 ^a _b ± 0.39	12.50 ^d _d ± 0.024	13.74 ^d _e ± 1.29	20.25 ^d _d ± 2.91	23.49 ^c _e ± 2.64	28.4 ^d _f ± 0.74
4	21.91 ^c _a ± 0.13	37.27 ^b _b ± 1.44	12.07 ^c _c ± 0.90	13.58 ^d _d ± 1.45	20.98 ^c _e ± 1.80	24.84 ^d _f ± 0.94	20.52 ^c _e ± 0.04

Values are mean ± standard deviation ($n = 6$). Mean values having different superscript letters in columns and subscript letters in rows differ significantly at ($P \leq 0.05$).

19.01. Similar values were reported by Zanoni et al.^[28] and Ramandeep and Geoffrey.^[32] For the metabisulfite treated sample, the dehydration resulted in a $b+$ value less than that of the control. GA treated samples displayed a decrease in $b+$ value. However, differences between most GA treatments were not significant ($P \leq 0.05$).

The decrease in $b+$ values due to dehydration revealed by the present study is in line with several reports.^[28,33] However, it is at variance with what is expected. Dehydration is expected to promote isomerization of the trans carotenoids to the yellow cis-isomers.^[33] Isomerization, especially of lycopene, is to increase the cis-isomer and, consequently, the $b+$ value. Shi et al.^[33] attributed the resulting decrease of the b value of tomato homogenate on dehydration to inability of color measurement to show the relative composition of all trans- and cis-isomers.

Lightness (L) Value

The fresh blanched control displayed a lightness (L) value of 38.5, which declined to 27.8 subsequent to dehydration (Table 8). The decline of the L value of the blanched control on dehydration is higher than that reported by Zanoni et al.,^[28] but lower than observed by Ramandeep and Geoffrey.^[32] The metabisulfite treated sample showed an L value of 32.85. The L values of the GA treated samples increased in a concentration dependent manner and were between 27.5 and 36. GA at 5 and 7.5% had comparable L values. Samples treated with GA at 10% showed an L value of 36. These findings indicated clearly that GA at 5–10% resulted in L values higher than that displayed by the control. Furthermore, at its highest concentration (10%) GA resulted in L value comparable to that of fresh tomatoes. Using L value as a parameter or index to measure color differences and extent of browning, it is clear that GA inhibited browning and prevented its extension for up to 4 months of storage.

a/b Ratio

The a/b ratio for tomatoes, an indicator of ripeness, is used as an index for color quality^[24,28,34] and has a high correlation with lycopene content.^[35] An a/b value more than 2 indicates excellent red color, while lesser values denote immaturity or deterioration in color. The initial a/b value of the fresh produce (0.828) was less than that reported by Batu.^[34] Table 9 shows that dehydration increased a/b value of the control to 1.76, which is comparable to that reported by Zanoni et al.,^[28] but is less than that obtained by Porretta and Giovanna.^[25] The metabisulfite treated samples displayed an a/b ratio of 1.95, which is significantly ($P \leq 0.05$) higher than that of the control. GA at 7.5% yielded a/b value comparable to the metabisulfite treatment. However, higher and lower GA concentrations affected lesser values.

CONCLUSIONS

Dehydration and subsequent storage promoted discoloration and non-enzymatic browning of tomatoes. Sodium metabisulfite, a conventional color preservative of dehydrated vegetables, increased the initial and during storage pH and its effects as a color preservative decreased with time. Gum Arabic, a natural product, was more effective (at 5–10%) in suppressing non-enzymatic browning and as a color preservative of dehydrated

Table 7 Yellowness (b) values of dehydrated tomato pretreated with gum arabic at different storage periods.

Storage period (months)	Control	1% Na ₂ S ₂ O ₅	1% Gum Arabic	2.5% Gum Arabic	5% Gum Arabic	7.5% Gum Arabic	10% Gum Arabic
Zero	19.04 ^a ± 0.27	15.69 ^{ab} ± 0.17	11.38 ^a ± 1.05	12.23 ^d ± 0.48	12.01 ^a ± 1.35	10.36 ^e ± 0.93	11.62 ^a ± 0.57
1	16.14 ^b ± 0.79	12.41 ^b ± 1.32	7.87 ^b ± 0.042	7.72 ^c ± 1.24	11.005 ^b ± 1.23	10.055 ^b ± 1.90	12.725 ^b ± 0.95
2	13.71 ^c ± 1.18	24.38 ^c ± 0.31	7.86 ^c ± 0.64	8.20 ^b ± 0.52	11.52 ^d ± 0.77	13.88 ^a ± 0.36	18.79 ^e ± 1.27
3	13.21 ^d ± 0.79	24.53 ^d ± 0.46	6.26 ^c ± 0.098	6.8 ^b ± 0.39	11.68 ^a ± 0.91	12.29 ^d ± 0.22	18.95 ^c ± 0.31
4	14.59 ^e ± 0.07	23.19 ^c ± 1.22	7.39 ^d ± 0.43	8.38 ^c ± 1.62	12.58 ^d ± 0.28	14.62 ^e ± 1.53	14.14 ^e ± 1.03

Values are mean ± standard deviation (*n* = 6). Mean values having different superscript letters in columns and subscript letters in rows differ significantly at (*P* ≤ 0.05).

Table 8 Lightness (L) values of dehydrated tomato pretreated with gum arabic at different storage periods.

Storage period (months)	Control	1% Na ₂ S ₂ O ₅	1% Gum Arabic	2.5% Gum Arabic	5% Gum Arabic	7.5% Gum Arabic	10% Gum Arabic
Zero	27.08 ^a ± 1.11	32.84 ^b ± 1.83	27.53 ^a ± 0.29	28.89 ^a ± 1.34	31.72 ^d ± 2.25	31.89 ^a ± 1.98	35.88 ^a ± 3.18
1	31.04 ^b ± 0.28	31.5 ^b ± 1.41	28.37 ^b ± 1.00	29.16 ^a ± 1.59	23.38 ^b ± 1.68	29.9 ^b ± 0.38	29.18 ^a ± 0.01
2	32.29 ^c ± 1.32	39.58 ^b ± 0.05	27.94 ^c ± 0.53	30.34 ^d ± 0.39	35.24 ^c ± 0.32	34.54 ^c ± 0.55	34.97 ^b ± 0.96
3	33.69 ^d ± 0.33	41.31 ^d ± 0.26	29.64 ^d ± 0.08	31.09 ^d ± 0.15	35.53 ^d ± 1.54	36.85 ^d ± 1.51	37.48 ^c ± 0.07
4	32.89 ^e ± 0.76	38.15 ^c ± 0.96	28.12 ^c ± 0.02	30.21 ^c ± 0.99	33.78 ^e ± 2.11	35.23 ^e ± 0.96	32.33 ^d ± 0.49

L value of fresh tomato = 38.5 ± 0.20.

Values are mean ± standard deviation (*n* = 6). Mean values having different superscript letters in columns and subscript letters in rows differ significantly at (*P* ≤ 0.05).

Table 9 a/b ratio of dehydrated tomato pretreated with gum arabic at different storage periods.

Storage period (months)	Control	1% Na ₂ S ₂ O ₅	1% Gum Arabic	2.5% Gum Arabic	5% Gum Arabic	7.5% Gum Arabic	10% Gum Arabic
Zero	1.76 ^a ± 0.03	1.95 ^a _b ± 0.09	1.68 ^a _c ± 0.06	1.64 ^a _c ± 0.14	1.56 ^a _d ± 0.046	1.94 ^a _b ± 0.13	1.37 ^a _e ± 0.12
1	1.27 ^b _a ± 0.002	1.56 ^b _a ± 0.08	1.59 ^b _a ± 0.08	1.39 ^b _a ± 0.07	1.26 ^b _a ± 0.07	1.33 ^b _a ± 0.07	1.39 ^b _b ± 0.01
2	1.57 ^c _a ± 0.09	1.53 ^c _a ± 0.01	1.69 ^c _a ± 0.05	1.78 ^c _b ± 0.04	1.57 ^c _a ± 0.14	1.70 ^c _a ± 0.08	1.45 ^c _a ± 0.03
3	1.69 ^d _a ± 0.04	1.58 ^d _b ± 0.01	1.99 ^d _c ± 0.03	2.02 ^d _c ± 0.07	1.73 ^d _d ± 0.12	1.91 ^d _c ± 0.18	1.49 ^d _f ± 0.02
4	1.50 ^e _a ± 0.02	1.61 ^e _b ± 0.14	1.63 ^e _c ± 0.03	1.64 ^d _c ± 0.14	1.67 ^d _d ± 0.11	1.07 ^d _d ± 0.11	1.46 ^e _a ± 0.11

a/b ratio of fresh tomato = 0.828 ± 0.020.

Values are mean ± standard deviation (n = 6). Mean values having different superscript letters in columns and subscript letters in rows differ significantly at (P ≤ 0.05).

tomatoes than 1% sodium metabisulfite for up to 4 months of storage at ambient temperature. Gum arabic is a potential substitute for metabisulfite as a color preservative for dehydrated tomatoes.

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