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Effect of packaging and chemical treatment on storage life and physicochemical attributes of tomato (*Lycopersicon esculentum* Mill cv. Roma)

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Fresh fruits and vegetables are inherently more liable to deterioration under tropical conditions characterized by high ambient temperatures and humidity. In determining the effects of chemical treatment on tomatoes (*Lycopersicon esculentum* Mill cv. Roma), fruits purchased at turning stage of ripening were packaged in low density polyethylene bags (60 µ) containing wooden dust particles moistened with 400 ppm potassium permanganate solution. Samples were treated with hot water dip, boric acid (H_3BO_3) dip at 1000 ppm, $CaCl_2$ dip at 10,000 ppm, a combination of H_3BO_3 and calcium chloride treatment as well as control. Results of chemical treatment showed increase in weight loss, pH, and a slight increase in moisture content. Total soluble solids and titratable acidity of samples showed a steady decrease, with data on physicochemical qualities collected at 7 days interval. Fruits stored with hot water and combination of H_3BO_3 and $CaCl_2$ treatments showed higher keeping quality. Shelf life elongation treatments used at tropical ambient temperature of 30 ± 2°C was able to preserve tomato fruits for 21 days from spoilage and microbial attack while retaining its colour and other physicochemical properties.

Key words: Tomato, shelf life, packaging, respiration, pretreatment.

INTRODUCTION

Post-harvest loss of fruits and vegetables are a matter of concern especially for countries whose economy is based on agriculture. Horticultural crops due to high moisture content are inherently more susceptible to deterioration especially under high temperature conditions. Consequently, postharvest losses of fruits and vegetables are extremely high in Nigeria (30 - 50%), exacerbated by poor marketing, distribution and storage facilities (Aworh, 2009). Tomato (*Lycopersicon esculentum* Mill) is one of the very perishable fruits and it changes continually after harvesting (Babitha and Kiranmayi, 2010). Depending on the humidity and temperature, it ripens very quickly,

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ultimately resulting in poor quality as the fruit becomes soft and unacceptable. Upon harvest, many processes affecting quality loss sets in, thus limiting storage life by factors such as transpiration, postharvest diseases, increased ripening and senescence. Unlike other chilled perishable foods, fresh produce continues to respire after harvesting (Padmini, 2006). Respiration is affected by the intrinsic properties of fresh produce as well as various extrinsic factors, including ambient temperature.

Packaging fresh and unprocessed fruits and vegetables poses many challenges for packaging technologists in Nigeria and Sub-Saharan Africa. The quality of fresh produce is markedly dependent on growing conditions, minimizing bruising and other damage during harvesting and processing (Galic et al., 2011). Theoretically, an ideal package has a perfect chemical inertia that allows the food product to hold its original characteristics. But in reality, there are interactions between the package and the food product. These interactions depend not only on the package system itself, but also on the intrinsic nature of the preserved food product (Casp et al., 1999). With the high rate of spoilage of harvested food produce exacerbated by increased respiration and ethylene production in tropical regions of the globe, producers are faced with the challenge of shelf life extension of these produce. Several authors have reported the use of pretreatment with different compounds either in isolation or in combination with other preservation methods (Wang et al., 2010; Workneh et al., 2012; Tigist et al., 2013) for extension of storage life of fresh harvested produce.

Tomatoes and other fruits and vegetables in Nigeria are commonly transported at long distance haulage either loose or packed in raffia baskets, jute bags, fiberboard cartons and other improvised containers made from metal, plastic and wood. The traditional basket of the 'inverted cone' design offers little protection to perishable produce (Aworh, 2009). Since they invariably have no handles, the produce is compressed each time they are lifted as the pressure is transmitted inwards. Their rough surfaces puncture the produce accelerating decay and physiological breakdown. Primary modes of tomato transportation to processing facilities and retail outlets include road and rail with road transportation being the more preferred mode of transport for the harvested produce (Olayemi et al., 2010; Sibomana et al., 2016). This research therefore seeks to develop an appropriate method of polyethylene packaging and to determine the best chemical treatment required for storage life elongation of indigenous tomato varieties, with minimal or no loss in quality at ambient conditions.

MATERIALS AND METHODS

Experimental site and materials

The research was conducted at the food processing laboratory, Department of Food Technology, University of Ibadan, Ibadan, Nigeria. Indigenous Roma-VF tomato (*L. esculentum* Mill.) used for this research work, were purchased from Shasha, a local market in Ibadan, South West Nigeria. Tomato cultivar was purchased at turning stage of ripening; pink colour extending from blossom end, covering 10 to 30% of fruit (Rubatzy and Yamaguchi, 1997). Tomato fruits were then transported to the laboratory and selected for uniformity of colour, size and freedom from defects. Upon sorting, tomato was gently washed by hand, dried, before being used in subsequent experiments.

Chemical treatment and packaging

Tomato fruit at turning stage of ripeness were divided into five lots, with each lot having a different chemical treatment. Treatments given to samples include sample A, no treatment; sample B, hot water treatment; sample C, hot water and H_3BO_3; sample D, hot water and $CaCl_2$; sample E, hot water, H_3BO_3 and $CaCl_2$ treatment. Hot water treatment was carried out by hot water dip at 55°C for 5 min in a thermostated water bath. H_3BO_3 treatment was carried out by dipping tomato fruits in 1000 ppm boric acid solution for 30 to 60 s, removed and dried (Sammi and Tariq, 2007). $CaCl_2$ treatment was also done by dipping tomato fruits in 10,000 ppm $CaCl_2$ solution for 1 to 2 min, removed and dried (Babitha, 2006; Sammi and Tariq, 2007). For $KMnO_4$ treatment, 400 ppm saturated solution of $KMnO_4$ was prepared; it was then wetted in saw dust, tied in a stay cloth and introduced into the packaged tomato fruits. All treated fruits were packaged in perforated low density polyethylene (LDPE) bags of 60 μ measuring 12 by 9.5 cm, containing saturated solution of $KMnO_4$ which was wetted in saw dust, placed in stay cloth material and then packaged with tomato fruit. Samples were then placed in paper boards, with each packaging material containing two tomato fruits each and placed in the paper board. Packaged samples placed in the paper board were then stored at ambient temperature of 30 ± 2°C.

The stage of ripeness of each tomato fruit was determined using the USDA standard for the classification of matured tomato. Fruits were also evaluated on a 7-point scale by means of visual colour description with score 1, for turning colour stage; 2 for 30% pink; 3 for 70% pink; 4 for 30% light red; 5 for 70% light red; 6 for 30% red; and 7 for 70% red.

Physiological weight loss

The physiological weight loss (PWL) was determined according to the method of Tefera et al. (2007). PWL was calculated for the storage days and converted to percentage of initial weight recorded for each sampling interval. Obtained values of PWL were expressed in percentage with respect to different treatments.

pH and titratable acidity (TA)

Approximately 80 mL of distilled water was added to samples which has already been cut to smaller size and milled. Puree obtained after milling was filtered using a muslin cloth into a beaker. The electrode of the pH meter was then placed in 60 mL of filtrate obtained from sample puree and used for determination of pH values. A pH meter (EDT instrument, model: BA 350) was used for determining the pH.

A total of 50 mL of filtered juice was diluted with 100 mL of distilled water. Diluted juice was placed in a 250 mL conical flask and 4 drops of phenolphthalein indicator added. It was then titrated with 0.1 N NaOH with pH of 8.1 until indicator showed a pink colouration. The appearance of the light pink colour was marked as the end point. TA was calculated from titer values obtained and was expressed as percentage of predominant acid present in fruit. Citric

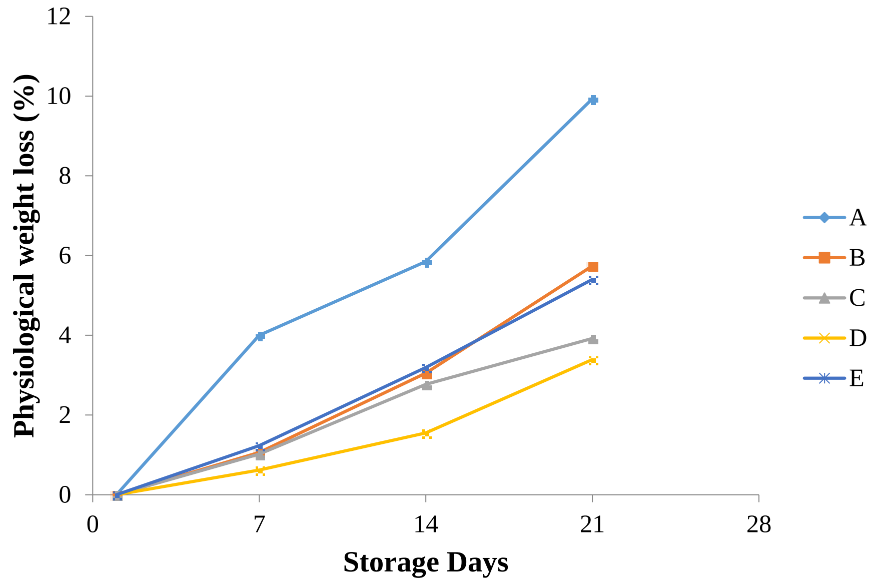

Figure 1. Physiological weight loss (%) of treated fruits. A = sample A; B = sample B; C = sample C; D = sample D; E = sample E.

acid was used as the predominant acid present, with 0.007 used as the citric acid factor.

Total soluble solids (TSS)

TSS was determined using a hand held refractometer, Atago, Japan and according to the methods of Wills and Ku (2001). Samples of different chemically treated fruits were milled with 80 mL of distilled water. A drop of milled samples was placed on the refractometer prism, from which results were taken. Values of TSS taken were expressed as degree (°) Brix.

Moisture content

Moisture content of tomato expressed in percentage was determined by method described by AOAC 925.45 using equation 1 (Horwitz, 2000). Empty crucibles were dried in an oven at 100°C for 30 min and weighed (W1). A total of 10 g of tomato was placed in a crucible, accurately weighed and the combined weight recorded as W2. The crucible was kept in an oven at 100 to 105°C for 6 to 12 h until a constant weight was obtained. The oven dried sample were then placed in a dessicator and allowed to cool. The crucibles were weighed again after cooling (W3).

$$\text{Moisture content (\%)} = \frac{W2-W3}{W2-W1} \times 100 \qquad 1$$

W1 = Initial weight of empty crucible; W2 = weight of crucible + banana flour sample; W3 = final weight of crucible + banana flour sample.

Statistical analysis

Analyses were done in triplicates with results presented as mean values ± standard deviation. Means were compared using analysis of variance with obtained results separated using Duncan multiple comparison test at significant levels of $p < 0.05$. Statistical analysis was done using SPSS 19 for windows (SPSS Inc., Chicago, Illinois) statistical software package.

RESULTS AND DISCUSSION

Results on quality parameters of tomato were analyzed for 21 days and collected at an interval of seven days: Day 1, 7, 14 and 21 of storage period. Obtained results of analysis showed that treatments differed in its effect on quality parameters among various samples examined.

Physiological weight loss (PWL) of treated tomato samples

Loss of weight progressively increased with storage time. Weight loss of fresh tomato is primarily due to transpiration and respiration. Water is lost by transpiration due to differences in vapour pressure of water in atmosphere and tomato surface (Tasdelen and Bayindirli, 1998). Respiration causes weight reduction because a carbon atom is lost from the fruit each time a CO_2 molecule is produced from an absorbed oxygen molecule and evolved into the atmosphere (Bhowmik and Pan, 1992).

PWL was recorded in all samples, with sample A showing the highest loss in weight of 9.93%, recorded on the last day of storage (Figure 1). This was because sample A received no treatment, hence the rate of respiration was not reduced, when compared to other samples with chemical treatment. This result is in agreement with the work of Tefera et al. (2007) who stated that packaging of fruits reduced PWL of mango

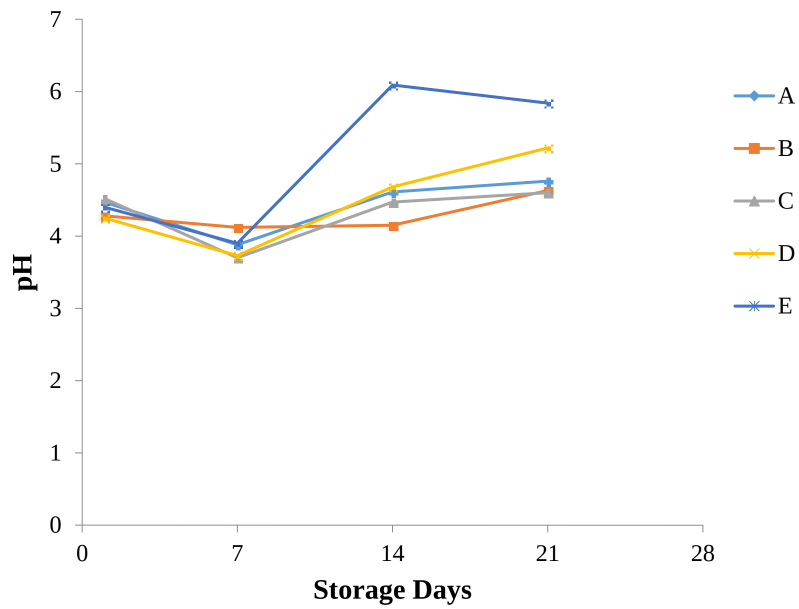

Figure 2. pH of treated tomato fruits. A = sample A; B = sample B; C = sample C; D = sample D; E = sample E.

fruits after 28 days of storage. The observed low weight loss trend in the other samples may be related to water vapour accumulation within the LDPE material during storage. This was as a result of the reduction in O_2 content and an increase in CO_2 content leading to the accumulation of water vapour. Thus packaged and chemically treated tomato samples B, C, D and E showed reduced PWL compared to the unpacked samples. This result agrees with the findings of Workneh et al. (2012) who determined the effects of preharvest treatment, disinfections, packaging and storage environment on quality of tomato. The introduction of potassium permanganate, boric acid and calcium chloride in the packaged fruits contributed in reducing weight loss. Potassium permanganate is said to be an ethylene degrading chemical which degrades ethylene into water and carbon dioxide. Water accumulated within the packaging materials created a high humid environment thereby retarding transpiration and water loss (Thompson, 1994; Roth, 1999).

pH and TA of treated tomato samples

Generally, the pH of fruits increases as fruits undergo ripening. Citric acid has also been shown to be the main acid in tomato juice, with pH of fruit normally between 4.0 and 4.5 (Babitha and Kiranmayi, 2010). From results obtained in this study, the pH of stored tomato fruit increased as the days of storage increased in all treated samples and in control (Padmini, 2006). pH was within range of acid recorded in fruits at day 1 of storage due to the fact that tomato fruit was still at turning stage of ripeness. However, there was recorded decrease in pH (3.70 to 4.12) of samples in day 7 of storage as stored samples became more acidic, before showing an increase in pH on days 14 and 21 of storage respectively (Figure 2). Of all samples analysed, sample E was least acidic (6.09 ± 0.75) at day 14 of storage while sample C was the most acidic (3.70 ± 0.17) at day 7 of storage.

Acidity is often used as an indication of maturity as acid decreases on ripening of fruit. It has also been reported that upon ripening of tomato fruit, malic acid disappears first, followed by citric acid, suggesting the catabolism of citrate via malate. Result of analysis shows that there was a concomitant decrease in TA, from 8.7 to 3.9 across all treated tomato fruit sample as the storage days increased. Sample C showed the least TA of 3.9 ± 0.74 among all samples examined at day 21 of storage. Reduction in TA may be attributed to a decrease in respiration rate caused by low density polyethylene packaging which led to accumulation of moisture in the packaging material. Sample C showed a steady decrease in TA with the exception of day 14 were there was a significant increase before decreasing on day 21 of storage (Figure 3). Sample B showed highest amount of TA which was statistically significant, apart from control. This may be due to its treatment with $KMnO_4$ only thus agreeing with Wills et al. (1981) who stated that $KMnO_4$ contributes to an increase in the CO_2 concentration as ethylene is degraded into CO_2 and water.

Moisture content of treated tomato samples

Water comprises about 80 to 90% of the fresh weight of tomato fruit with the size of the fruit influenced by availability of water to the plant (Babitha and Kiranmayi,

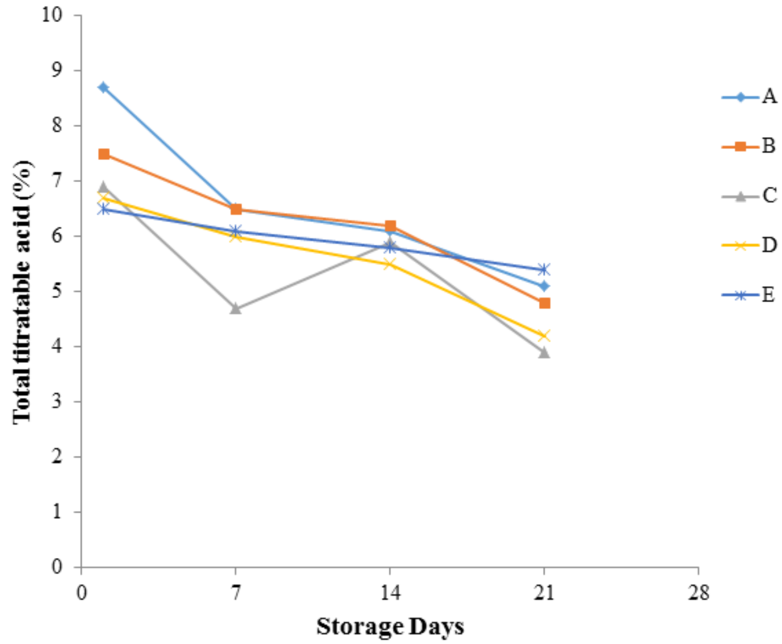

Figure 3. Total titratable acidity (%) of treated fruits. A = sample A; B= sample B; C = sample C; D = sample D; E = sample E.

Table 1. Chemical changes in tomato samples during different days of storage.

Properties	Sample					
	Day	A	B	C	D	E
Moisture content (%)	1	91.20 ± 0.40[ab]	91.50 ± 0.22[a]	90.30 ± 0.03[c]	90.90 ± 0.67[b]	90.10 ± 0.11[ab]
	7	91.70 ± 0.09[a]	90.80 ± 0.09[c]	90.90 ± 0.01[bc]	91.30 ± 0.19[ab]	91.60 ± 0.41[a]
	14	91.60 ± 0.15[a]	90.60 ± 0.02[c]	90.93 ± 0.01[bc]	91.00 ± 0.66[bc]	91.50 ± 0.70[ab]
	21	92.50 ± 0.01[a]	92.20 ± 0.15[ab]	91.90 ± 0.84[b]	91.90 ± 0.20[b]	92.40 ± 0.82[a]
TSS (^{o}Brix)	1	3.20 ± 0.01[ab]	2.40 ± 0.03[c]	2.70 ± 0.00[bc]	3.60 ± 0.04[a]	2.20 ± 0.30[c]
	7	3.30 ± 0.66[a]	1.80 ± 0.01[bc]	0.90 ± 0.00[d]	2.03 ± 0.10[b]	1.30 ± 0.12[cd]
	14	3.00 ± 0.22[a]	1.00 ± 0.00[b]	1.20 ± 0.01[b]	1.30 ± 0.00[b]	1.10 ± 0.28[b]
	21	2.50 ± 0.06[a]	2.50 ± 0.67[a]	2.00 ± 0.00[a]	2.10 ± 0.10[a]	1.90 ± 0.19[a]
TSS/TA	1	0.37 ± 0.07[b]	0.32 ± 0.03[b]	0.39 ± 0.02[b]	0.54 ± 0.02[a]	0.34 ± 0.06[b]
	7	0.49 ± 0.01[a]	0.28 ± 0.01[c]	0.19 ± 0.01[d]	0.42 ± 0.01[b]	0.22 ± 0.05[d]
	14	0.49 ± 0.07[a]	0.16 ± 0.04[b]	0.20 ± 0.05[b]	0.24 ± 0.04[b]	0.19 ± 0.03[b]
	21	0.49 ± 0.00[a]	0.52 ± 0.05[a]	0.51 ± 0.07[a]	0.50 ± 0.05[a]	0.35 ± 0.04[b]

Means in each row with the same alphabet are not significantly different ($p > 0.05$) by Duncan multiple test. Values are means ± standard deviation (n = 3). TSS = total soluble solids; TSS/TA = sugar-acid ratio; sample A = no treatment; sample B = hot water treatment; sample C = hot water and H_3BO_3 treatment; sample D = hot water and $CaCl_2$ treatment; sample E = hot water, H_3BO_3 and $CaCl_2$ treatment.

2010). Ripening in fruits is proceeded by softening, with the resultant effect of increased moisture content of the fruits. There was a slight significant increase in moisture content of samples A, C, D and E (Table 1) as the storage period increased. Sample B showed a steady decline in moisture content on days 7 and 14, due to the hot water treatment which reduced enzymatic activities of ripening and softening of the samples. As observed in all samples during storage days, chemical treatment did not inhibit the action of ripening, cell wall break down and softening of all samples examined. Hence enzymatic action of ripening and cell wall break down continued during storage with the resultant rise in moisture content as the storage days increased.

Total soluble solids (TSS) of treated tomato samples

In tomato fruit, conversion of starch to sugar is an important index of ripening (Kays, 1997). TSS for sample A was the highest among all five samples examined. This was due to increase in ripening of sample A as a result of no treatment. Treated samples B, C, D and E showed low TSS values due to various chemical treatments which delayed ripening to a certain degree of storage. As reported by the work of Tigist et al. (2013), untreated tomato samples stored at ambient temperature conditions recorded higher TSS values of between 4.23 and 5.22°Brix. Higher TSS values are attributed to the absence of chemical treatment in the samples used for the study as compared to TSS values obtained from samples used in this study. Samples B and E showed low Brix values of 1.0 and 1.1 on day 14 of storage while sample A recorded a significantly high Brix value of 3.3 on day 7 of storage. Sample C showed a drastic decline in TSS on day 7 of storage as ripening was really slowed down, before showing an increase on days 14 and 21 of storage due to the effect of H_3BO_3 treatment on the tomato fruit (Table 1). Result of this study agrees with the work of Wang and Moris (1993) who reported that H_3BO_3 reduces the rate of ethylene and CO_2 production in fruits thereby reducing the rate of respiration and ripening.

Sugar-acid ratio of treated tomato samples

From result of experiment, sugar-acid (TSS/TA) ratio was significantly highest in sample D on day 1 and samples A, B, C and D on day 21 in both treated and untreated tomato samples. TSS/TA ratio increased in day 7 of storage for sample A and remained stable on days 14 and 21 of storage period compared to the treated samples B, C, D and E that showed variations in their TSS/TA ratio. Due to chemical treatment used for storage, samples B, C, D and E showed significantly low rate of senescence in days 7 and 14 (Table 1) of storage period, hence low occurrence of TSS/TA ratio was observed during those storage days. Apart from its use as a maturity index, TSS/TA ratio is employed as ripening index for both tropical and subtropical fruits (Yahia et al., 2011; Guerreiro et al., 2016). According to Fawole and Opara (2013), TSS/TA value plays an important role in fruit taste which is a quality gauge in the processing of juice in the food and beverage industry. The sugar-acid ratio is also used as a better predictor of tomato taste as it involves the specific measurement of sucrose, fructose and glucose contents of the fruit (Beckles, 2012; Sibomana et al., 2016). Flavour characteristics of processed tomato products have also been reported to be influenced by the balance of sugar and acid contents in the fruit (Garcia and Barrett, 2006; Tigist et al., 2013). Sample D was significantly high ($p < 0.05$) on days 1 (0.54 ± 0.02) and 21 (0.50 ± 0.05) of storage period indicating higher percentage of sugar and flavour when compared to other tomato samples.

Conclusion

Tomato samples that were treated exhibited longer storage periods with samples stored using hot water treatment and $KMnO_4$ showing a higher keeping quality. Also samples stored with the combination of $KMnO_4$, H_3BO_3 and $CaCl_2$ equally exhibited high storage ability. These treatments were able to keep the tomato fruits for 21 days without spoilage and recorded little changes in their physicochemical properties. H_3BO_3 treated sample showed high ripening rate compared to other treated fruits while samples B and E showed higher keeping quality. It can therefore be implied from results obtained from this study that the combination of chemical treatments on ripe (turning stage) tomato fruit and packaged in low density polyethylene material can ensure that tomato keeps for 3 to 4 weeks at tropical ambient temperature condition of 30 ± 2°C.

Conflict of interests

The authors have not declared any conflict of interests.

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