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Development and Evaluation of Coatings from *Cactus opuntia* in Prolonging the Shelf-life of Mangoes (*Mangifera indica*) Stored under Evaporative Coolant System (ECS).

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ABSTRACT

Two different coatings were developed from the mucilage of Cactus and their effects were investigated on the quality and storability of mango fruits. The two experimental coatings were: Pure mucilage extracts (ME) and Mucilage extract mixed with 5ml glycerol (MEG) which served as plasticizer. The following parameters were measured : Weight loss, ascorbic acid content, pH, firmness and microbial qualities. Four hundred and eighty (480) mango fruits of "Ogbomosho" variety were stored for seven weeks at an average temperature of 27±2°C and relative humidity55-60% under Evaporative Coolant System(ECS) . Prior to storage, the mango samples were surface sterilized using 100mg/^{1} sodium hypochlorite and arranged randomly into three treatments, the control (untreated) and two coating treatments. The overall result showed that Cactus mucilage is effective in extending the shelf-life of mango fruits when compared to untreated in the order, MEG>ME>Control. Result revealed that coating hindered the growth of microorganisms significantly (P<0.05).

Keywords: Cactus, Mango, Evaporative Coolant System(ECS)

INTRODUCTION

Mango (*Mangifera indica* L) is a very delicious tropical fruit which belongs to the family *Anacardiaceae.* It is an abundant source of vitamins, minerals and is famous for its excellent flavor, attractive fragrance and nutritional value. It is emerging as a tropical export crop and is produced in about 90 countries in the world with a production of over 820,877MT. The magnitude of post harvest losses in fresh fruits and vegetables is estimated between 5-25% in developed countries and 20-40% in developing countries, depending upon the commodity (FAO, 2001).

Edible films and coatings can be used to help in the preservation of fruit and vegetables because they provide a partial barrier to moisture, Oxygen and Carbondioxide, also improving mechanical handling properties, carrying additives, avoiding volatiles loss and even contributing to the production of aroma volatiles (Olivas & Barbosa-Ca´ novas, 2005).

Edible coatings may be composed of polysaccharides, proteins, lipids or a blend of these compounds (Mahmoud and Savello, 1992; Park *et al.*, 1994a, b; Guilbert *et al.*, 1996; Li and Barth, 1998; Arvanitoyannis and Gorris, 1999). Their presence and abundance determine the barrier properties of material with regard to water vapor, oxygen, carbon dioxide and lipid transfer in food systems (Guilbert *et al.*, 1996). However, none of the three constituents can provide the needed protection by themselves and so are usually used in a combination for best results (McHugh and Krochta, 1994a, b; Guilbert *et al.*, 1996).

Polysaccharides capable of forming gels in water are common throughout the plant kingdom. Some of them, such as the pectins in higher plants, carrageenans and agarose in algae, algal and bacterial alginates and xanthan, have been investigated in great detail. A relatively good understanding of their biochemistry and biophysical properties has already been achieved. By contrast, the composition properties or food applications of mucilages have been much less studied (Trachtenberg & Mayer, 1982). Mucilages are generally hetero-polysaccharides obtained from plant stems (Trachtenberg & Mayer, 1981). There are few studies on the composition and properties of Opuntia ficus-indica mucilage. McGarvie and Parolis (1979) observed that the mucilage extracted from the stems contains residues of D-galactose, D-xylose, L-arabinose, L-rhamnose and D-galacturonic acid.

Cactus mucilage may find applications in food, cosmetics, pharmaceutical and other industries. The complex polysaccharide is part of dietary fibre and has the capacity to absorb large amounts of water, dissolving and dispersing itself and forming viscous or gelatinous colloids (Dominguez-Lo´pez, 1995).

The present study is aimed at investigating the suitability of prickly pear cactus (O. ficus indica) mucilage as an edible coating to extend the shelf-life of mango fruits.

MATERIALS AND METHODS

Source of fruits and Coating materials

Ogbomoso mangoes, common consumer varieties, were purchased from a local market on the day after harvest and were immediately placed in ambient storage (27^{o}C ± 3).Uniform sized, defect-free fruits were selected. Cactus stems were obtained from a local farmer and were stored at 23^{o}C ± 1 prior to formation of the coating solution. Glycerol (99.5%) was purchased from Sigma Chemical Co.

Preparation of Coating solution

Cactus stems were peeled and cubed (1 cm^{3}). Samples were homogenized (20% w/v) in distilled water. The slurry was centrifuged for 10 min at 4500 × g and the supernatant obtained was used to prepare the edible coating (Sa´enz, Va´squez, Trumper, & Fluxa´, 1992).It was then pasteurized to form a pure mucilage extract .Mangoes were dipped in coating solution for 30secs, the excess coating was drained and the coated mangoes were dried in a forced-air dryer (20 ^{o}C) for 30 min. Mangoes dipped in distilled water were used as a blank. After the coating process, the mangoes were stored in an ambient temperature at 27 ± 3^{o}C and 50-65% RH for 6weeks. For each treatment and storage time, 40 fruits were coated. Firmness, Percentage weight loss and pH were determined from week 1-6 after coating.

Treatments

T_o (control):-Untreated mangoes; $T_{1:-}$ Mangoes coated with Pure mucilage extract (ME); T2:-Mangoes coated with mucilage extract mixed with 5ml glycerol (MEG) .
The treated and untreated fruits were packed in small plastic baskets and each basket contained 20 mango fruits. The baskets were stored at ECS temperature and relative humidity (27±2°C and 55-60%).

The evaporative cooling system

The evaporative cooler used for the study consisted of a double-walled rectangular brick construction with the interspace filled with riverbed sand saturated with water. The clay brick used in the wall construction was factory baked (at 600 ^{o}C) and was of dimensions 25.5 cm x 12.0 cm x 6 cm thick. The water used was clean and free of foreign matter so as to maintain previousness and avoid clogging of the sand.

The interior surfaces of the cooling chamber walls were given a smooth finish with 1.2 cm thick cement plaster, while a heat insulating cover of 1.9 cm thick particle board closed the top. The walls were built on a short plinth of concrete to prevent water seepage into the soil. Two framed doors of sawn wood were fixed one to each of the adjacent walls on a side to provide access to the 1.38 m^3 capacity chamber. These two doors were considered adequate for the needed thermal insulation against heat flux but an additional polystyrene foam board could be installed for more insulation. The permanent structure was erected in open space exposed to free air but shaded from direct solar radiation with an open sided shed of thatch.

Physiochemical analyses of fruits were carried out from week 1-7 after coating using the following parameters;

Weight loss: To evaluate weight loss, separate samples in 3 replicates of each treatment were used. The same samples were evaluated for weight loss each time at weekly intervals until the end of experiment. Weight loss was determined by the following formula:
Weight loss (%) = [(A−B)/A] x 100
Where A indicates the fruit weight at the time of harvest and B indicates the fruit weight after storage intervals (A.O.A.C., 1994).

Firmness: - firmness was measured as the maximum penetration force (N) reached during tissue breakage, and determined with a 5 mm diameter flat probe. The penetration depth was 5 mm and the cross-head speed was 5 mm s^{-1} using a TA-XT2 Texture Analyzer (Stable Micro Systems, Godalming, UK), MA. Mangoes were sliced into halves and each half was measured in the central zone.

pH:- after firmness analysis, mangoes were cut into small pieces and homogenized in a grinder. 10 g of ground mango was suspended in 100 ml of distilled water and then filtered. The pH of the samples were assessed using a pH meter (pH-526; WTW Measurement Systems, Wissenschaftlich, Technische Werksta¨tten GmbH, Wellhelm, Germany)

Ascorbic acid:- ascorbic acid content was measured using 2, 5-6 dicholorophenol indophenols' method described by A.O.A.C (1994).

Microbial analysis

Thirty grams of mango fruit pulps were removed aseptically from each treatment. The sample was then homogenized in peptone saline solution (8.5 g l^{-1} NaCl+1 g l^{-1} peptone (Oxoid, L34)) for 1 min in a stomacher (S400, Shanghai Scientific Instrument Co., Ltd., Shanghai, China). After making serial dilutions in peptone water, the samples were plated on different media as follows: (1) plate count agar (PCA, OxoidCM325) for isolating total aerobic psychrotrophic micro- organisms was incubated at 30^{o}C for 72 h (2) Sabouraud media (Oxoid CM41) for isolating yeasts and moulds was incubated at 25 ^{o}C for 120 h.
Colonies were counted and the results expressed as CFUg^{-1} of mangoes. Analyses were
carried out periodically in randomly sampled pairs of trays within 7 weeks. Two replicate counts were performed for each tray.

Statistics

The results of this investigation are means of seven measurements. To verify the statistical significance of all parameters the values of means ± S.E. were calculated.

RESULTS AND DISCUSSION

The effects of Mucilage coatings on firmness of mango fruits stored in ECS are shown in Fig.1 The mean ± SE values for the firmness of coated MEG and ME mangoes were 4778.57±420.50 and 3998.57 ±564.62 respectively while the mean±SE value for the firmness of uncoated mangoes was 3164.29± 774.34. Our results are similar to the findings by Yaman and Bayoindirli (2002) for cherries coated with Semperfresh™. The retention of firmness can be explained by retarded degradation of insoluble protopectins to the more soluble pectic acid and pectin. During fruit ripening, depolymerization or shortening of chain length of pectin substances occurs with an increase in pectinesterase and polygalactronase activities (Yaman and Bayoindirli, 2002). Low oxygen and high carbon dioxide concentrations reduce the activities of these enzymes and allow retention of the firmness during storage (Salunkhe *et al*., 1991). Patricia *et al*. (2005) also reported that refrigerated strawberries coated with wheat gluten-based films had a better firmness retention than control fruits. Sumnu and Bayindirli (1995) also noted that Semperfresh™, Jonfresh and Fomesa apple wax

were efficient in reducing the firmness change of Amasya apples during storage process. The same effects were observed for Anna apple treated with 1-MCP.

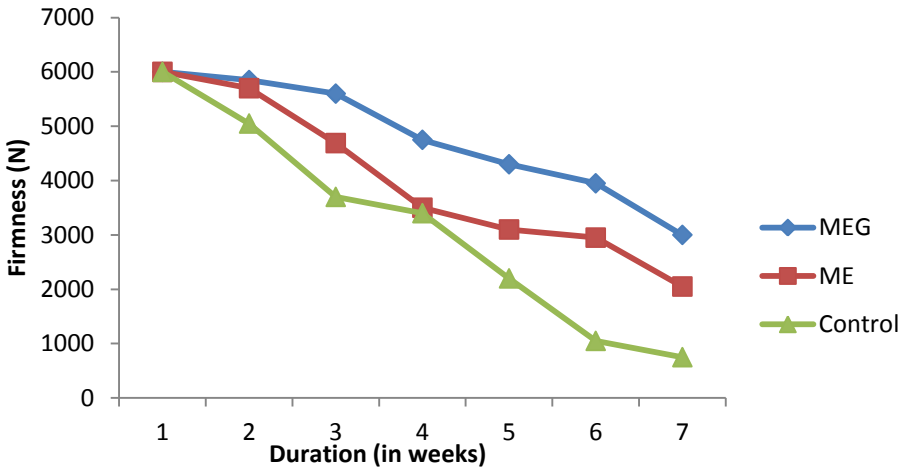

Fig1:Effect of mucilage coatings on firmness of mangoe fruit during storage in ECS

Addition of glycerol at 5% to the coating solution had little effect on the firmness of coated mangoes, not being statistically significant. Glycerol was added to increase the flexibility of the coating and hence avoided splitting on the coated fruit. Cracking of the coating lacking glycerol was not observed since water itself acted as a plasticizer, due to the high water activity of mangoes.

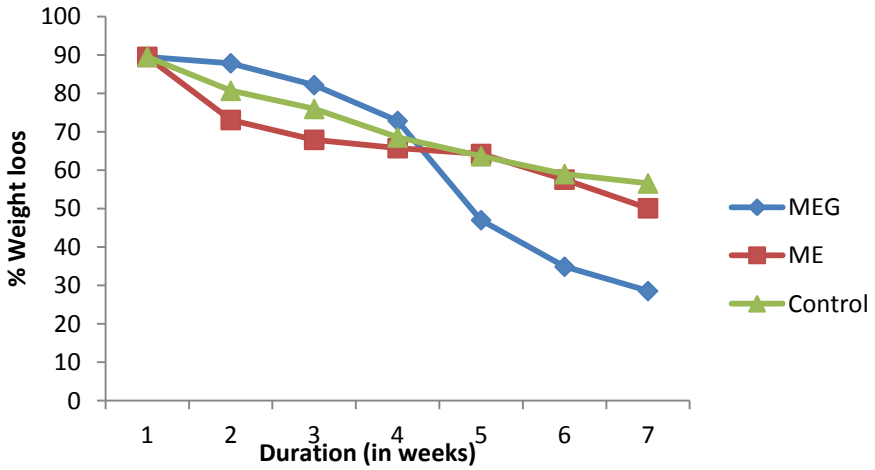

Fig 2:Effect of mucilage coatings on Weight loss of mango fruit during storage in ECS

Weight loss is an important index of post harvest of total storage life in the fresh produce. It is mainly attributed to the loss of water during metabolic processes like respiration and transpiration. The coating helps to reduce this further by forming a film on the top of the skin acting as an additional barrier to moisture loss (Togrul and Arslan ,2004). These barriers also reduce the oxygen uptake by the fruit which in turn slows down rate of respiration and associated weight loss from the fruit surface.The primary mechanism of moisture loss from fresh fruits and vegetables is by vapor-phase diffusion driven by a gradient of water vapor pressure at different locations (Yaman and Bayoindirli, 2002). The coatings (MEG and ME) caused a significant ($p \leq 0.05$) decrease in weight loss compared with control sample. The mean±SE value for the weight loss of MEG and ME were 63.25±9.803 and66.88± 4.71while the mean±SE value for the weight loss of uncoated mangoes was 70.56±4.56. The obtained results are in agreement with the findings of GarcÂ´ia *et al*. (1998a, b) for strawberries coated with starch-based coatings and those of Joyce *et al*. (1995), who reported that waxing extended the storage life of avocado both through a reduction in water loss and a modification of the internal atmosphere. Similar data were also obtained by Bai *et al*. (2003) while studying Gala apple, coated with 10% zein (natural corn protein). es. Chitosan and polyethylene wax (PE) coatings also provide good protection for Hami melon (Cong *et al*., 2007).

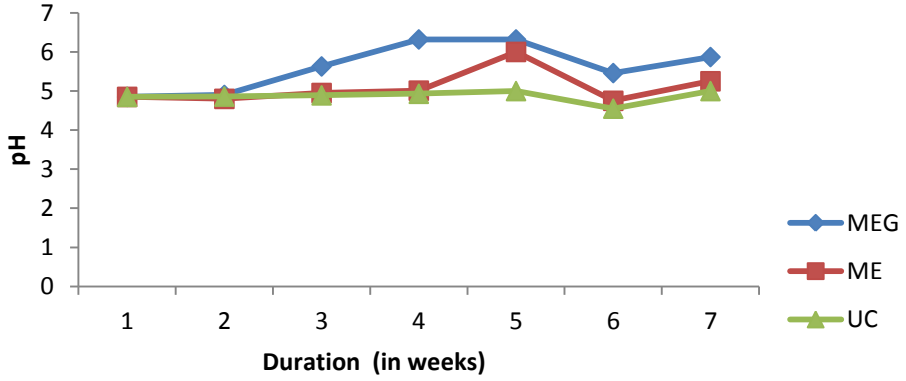

Fig 3:Effect of mucilage coatings on pH of mango fruit during storage in ECS

The pH of mango fruit gradually increased during storage. The mean±SE value for the pH of coated MEG and ME were 5.62±0.23 and 5.09±.17 while the mean±SE value for the pH of uncoated mangoes was 3.53±0.17. The differences between pH of treated and control fruits, were however not significant though, the control and *cactus* mucilage showed higher pH at the end of 8 weeks of storage (Fig. 3). This was probably because the semi-permeable *cactus* mucilage film formed on the surface of the fruit might have modified the internal atmosphere, i.e., the endogenous CO2 and O2 concentration of the fruit, thus retarding ripening (Lowings & Cutts, 1982; Bai *et al*., 1988).

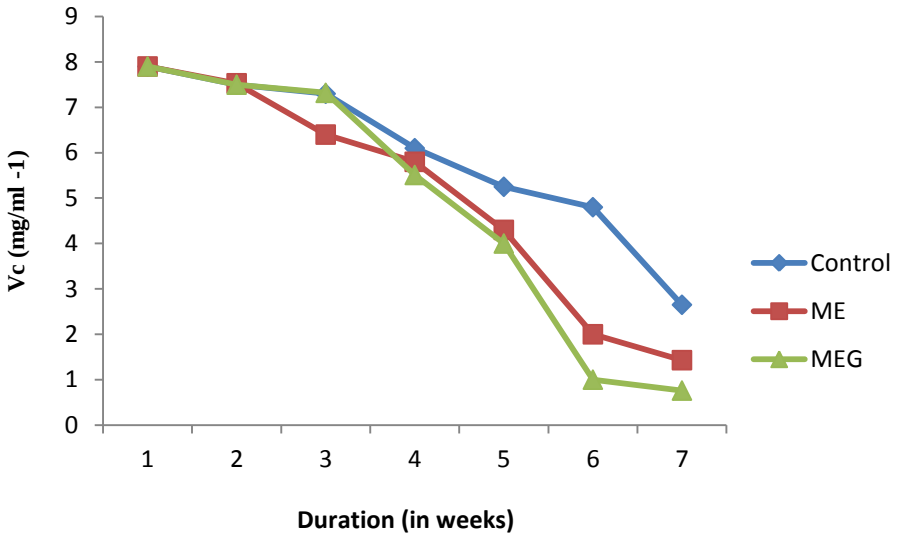

Fig 4:Effect of mucilage coatings on % Vitamin C of mango fruit during storage in ECS

Ascorbic acid is an important nutrient quality parameter and is very sensitive to degradation due to its oxidation (Veltman *et al*., 2000) compared to other nutrients during food processing and storage. The decrease in value of vitamin C observed in the samples with storage time could be as a result of oxidation reaction by residual oxygen in the headspace followed by anaerobic decomposition which may have been accelerated due to storage temperature (Burdulu *et al*., 2006). It has been demonstrated that both aerobic and anaerobic oxidation of L-ascorbic acid occur in freshly produced orange juice aseptically-filled in Tetra Brik cartons. The aerobic oxidation proceeds during the initial stage of the degradation process at a rate which

is dependent on the L-ascorbic acid concentration, dissolved oxygen level and temperature of storage (Roig *et al*., 1994). Kanner *et al* (1982) observed that long storage time leads to many breakdown products developed from juice constituents which seemed to affect and accelerate destruction of vitamin C of orange juice concentrate packaged aseptically. Maximum ascorbic acid in control treatment might be due to increased respiration causing loss of ascorbic acid. Ascorbic acid is susceptible to oxidative deterioration as well as mild oxidation of ascorbic acid results in the formation of dehydro ascorbic acid. The presence of oxygen accelerates oxidation process in fruits (Ahmad, 1982).

The mean±SE value for the coated MEG and ME vitamin C were 4.86± 1.15 and 5.05±0.71 for coated mangoes while the mean±SE value for the vitamin C for uncoated mangoes was 5.93±0.71.

The results are in line with findings of Kumar *et al.,* (2000): who found that ascorbic acid decreased with increasing period of storage in fruits of kinnow. The decrease in ascorbic acid was less in coated fruits as compared to the control. According to Bhattacharya (2004), the Vit. C content of fresh fruit was maximum just before ripening and then decreases due to the action of enzymes called ascorbic acid oxidase. Usually much of the ascorbic acid is transferred to juice and oxidized. The results agreed with the finding of Verma and Dashora (2000).

Microbial analysis

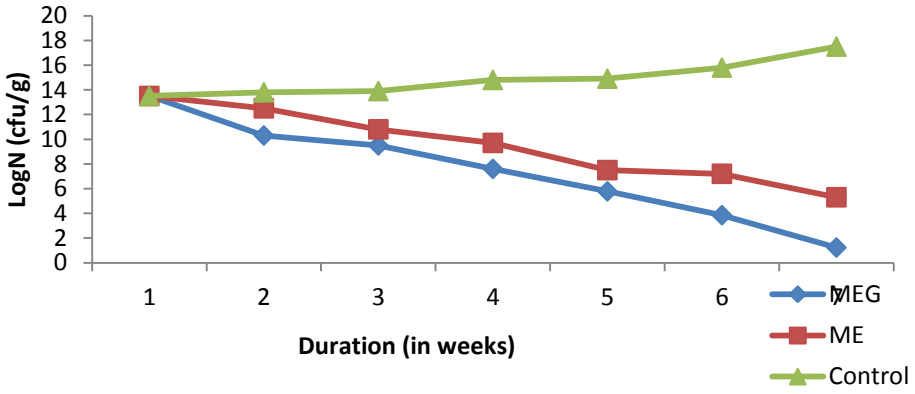

Fig 5:Effect of mucilage coatings on Total aerobic psychrotrophic count of mango fruit during storage in ECS

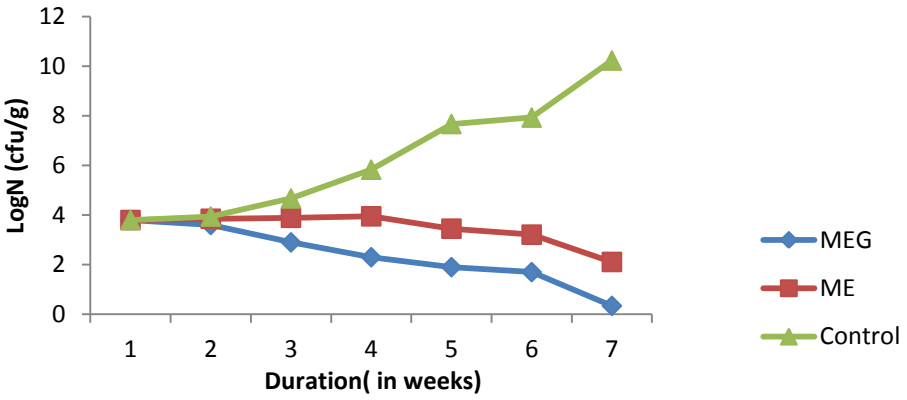

Fig 6:Effect of mucilage coatings on Moulds and yeast count of mango fruit during storage in ECS

The predominant microflora which influence the shelf life of fruits and vegetables are psychrotrophic bacteria (Garcia- Gimeno & Zurera-Cosano, 1997; Hotchkiss & Banco, 1992). Changes in the total aerobic Psychrotrophic count, total number of yeasts and moulds in mangoes stored for seven weeks at an average temperature of 27±2°C and relative humidity 55-60% are shown in Figs. 5 and 6. During the period of storage, coating significantly hindered the increase in total aerobic psychrotrophic count compared with the control samples (Fig. 5). Similar effect of coating was observed in reducing the growth of yeasts and moulds during the storage (Fig. 6). At the end of 7 weeks storage, virtually apparent differences were observed between coated MEG and ME and the control samples ($p<0.05$) at both temperatures.

At harvest, mangoes had 13.5 and 3.8 log CFU g-1 for total aerobic psychrotrophic and yeast and mold counts, respectively. Following 7 weeks of ECS storage at temperature of 27±2°C and relative humidity of 55-60%, the microbial populations of *Cactus* mucilage-treated mangoes were significantly reduced, the reduction being slightly more effective for yeast and mold counts from coated mangoes MEG and ME which were (0.34 log CFU g-1) and (2.11log CFU g-1) respectively than for aerobic Psychrotrophic counts from coated mangoes MEG and ME which were (1.23 log CFU g-1) and (5.30 log CFU g-1) respectively. Moreover, the yeast and mold from uncoated mangoes fruit significantly increases to (10.23log CFU g-1) while the aerobic Psychrotrophic

in the uncoated mangoes fruit significantly increases to (23.56log CFU g-1) , but were significantly reduced in *Cactus* mucilage-coated mangoes.

CONCLUSION

Applications of *Cactus* mucilage coatings to mangoes were shown to be beneficial in keeping the quality of the fruits in storage. Coating with *Cactus* mucilage slowed down the weight loss, reduced the ascorbic acid content, pH and the growth of microorganisms. The shelf-life of mangoes was increased at an average temperature of 27±2°C and relative humidity 55-60%. Textural analysis showed that prickly pear cactus mucilage could have a protective effect on mangoes, reflected by the greater firmness of coated samples during storage, which could reduce economic losses due to spoilage produced from mechanical damage during handling and transportation. The ECS temperature probably added to the coating effect and might have helped the product to maintain its own characteristics.

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