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Postharvest Behavior of Biriba [*Rollinia mucosa* (Jacq.) Baill.] Fruits at Different Storage Temperatures

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Biriba [*Rollinia mucosa* (Jacq.) Baill.] is delicate to handle and has a very short shelf life of less than a week thereby limiting its marketability. This study was conducted to determine the effect of varying temperatures on the postharvest behavior and storage life of biriba fruits. Storage temperature affected the physiological and physical characteristics of biriba fruit and subsequently its storage life. Higher respiration rates of 54.7 and 44.0 mg CO_2 $kg^{-1}h^{-1}$ were obtained at ambient condition and at 20°C, respectively, compared with 32.8 mg CO_2 $kg^{-1}h^{-1}$ at 13°C. However, the amount of ethylene produced was almost similar at all temperatures ranging from 38 to 41 µL $kg^{-1}h^{-1}$. Fruit softening coincided with the peak in ethylene production at ambient and at 20°C while at 13°C, it was on the second peak. Storage at ambient (29–31°C) and at 20°C resulted in 9.5% and 10.4% moisture loss, respectively. At 13°C, moisture loss was 7% at 15 d. Total soluble solids (TSS) and titratable acidity (TA) at the end of storage were the same but pH was slightly lower in fruits stored at 13°C than at the other temperatures. Though variations in pulp color and sourness were observed, pulp consistency, sweetness, and overall acceptability ratings of the pulp were the same. Fruits kept at ambient and at 20°C lasted for 5 and 8 d, respectively, whereas fruits kept at 13°C lasted for 15 d with satisfactory eating quality.

Key Words: biriba, *Rollinia mucosa* (Jacq.) Baill., storage life, storage temperature

INTRODUCTION

A lesser known fruit, biriba [*Rollinia mucosa* (Jacq.) Baill.] or wild sugar-apple, belongs to the family Annonaceae and is cultivated in tropical countries for its creamy pulp. Although this yellow fruit belongs to a different genus, it is similar to the *Annona* fruit cherimoya (Prance 2003). It is generally eaten fresh (George and Nissen 2003). The flesh is white to grayish, semi-translucent, soft and juicy with sub-acid taste and has numerous black seeds (Coronel 2011). It is quite rare in the Philippines and was introduced in 1910 and later in 1912 (Coronel 2011).

The fruit is large, conical or round, green when unripe, and turns yellow at ripening. Its surface is covered with protuberances which are readily bruised and which blacken with handling, giving it an unappealing appearance. The fruit will ripen fully in 3–5 d (Love and Paull 2011) after harvest. Once the fruit skin turns fully black, the pulp color and viscosity change to a clear mucous consistency then fermentation begins in 1 or 2 d. This delicateness, together with a shelf life of less than a week, has limited the commercial cultivation of biriba.

Although postharvest changes that occur in *Annona* fruits have been documented (George and Nissen 2003), there is limited information on the postharvest behavior of biriba fruits. *Annona* fruits are recognized to be climacteric with high respiration and ethylene production rates (Biale and Barcus 1970; Gross et al. 2016). This characteristic renders the fruits highly perishable and storage is limited due to rapid softening. Extension of the storage life of most tropical fruit is difficult due to chilling sensitivity (Pareek et al. 2011). Exposure of *Annona* fruits to temperatures below 8–12°C results in chilling injury showing symptoms of darkening and hardening of the skin, pitting, failure to develop full flavor, and mealy flesh (Kader and Arpaia 2002).

Temperature management is an important factor in maintaining the quality of fresh produce and low temperature is a common method of extending the storage life of commodities. Temperature affects the rate of metabolic processes such as respiration and ethylene production and influences ripening changes. Moisture loss and growth of microbial pathogens are also reduced at low temperature.

Although biriba is an introduced and rare fruit in the

Philippines, its cultivation is increasing. Knowledge of the postharvest behavior of biriba fruits at varying storage temperatures is useful in the development of appropriate technology to prolong its storage life. The objective, therefore, of this study is to determine the effect of storage temperature on postharvest behavior and storage life of biriba fruits.

MATERIALS AND METHODS

Freshly harvested biriba fruits were procured from a local farmer in Timugan, Los Baños, Laguna, Philippines in August 2016. Fruits weighing about 800 g each and free from apparent disease and insect damage were used in the experiment.

Fruits were placed inside a corrugated carton lined with newspaper. One layer arrangement of fruits inside the carton was maintained to avoid physical damage on the fruit during storage. The cartons of biriba fruits were then stored at 13°C, 20°C and at ambient condition (29–31°C, 69–83% RH).

To determine physiological changes during storage, the respiration and ethylene production rates were monitored daily using the static system. Three fruits which were almost similar in size were selected from each treatment. Each jar contained one fruit representing one replicate with a total of 3 replications per storage temperature. The concentrations of carbon dioxide (CO_2) and ethylene (C_2H_4) produced by the fruit were determined by gas chromatography. CO_2 was determined using the Shimadzu Gas Chromatograph (GC-2014) equipped with a thermal conductivity detector (TCD) and silica gel column with N_2 as the carrier gas. The column temperature was set at 90°C and operating at 90 mA current. For C_2H_4 production, a Shimadzu GC (GC-2014) equipped with Porapak QS column and flame ionization detector (FID) was used. Column temperature was set at 100°C; compressed air and H_2 were the gas carriers. Moisture loss, firmness, and visual quality rating (VQR) were monitored daily. Subjective fruit firmness determination was based on finger feel using the following scale: 1- firm, fruit does not yield to moderate pressure; 2- yielding, fruit yields slightly to moderate pressure; 3- soft, fruit yields readily to slight pressure; and 4- very soft, fruit yields very readily to slight pressure. The rating scale used for VQR is as follows: 9–8 excellent, field fresh; 7–6 good, defects are minor; 5–4 fair, defects are moderate; 3– poor, defects are serious; 2– limit of edibility; 1– non-edible. Defects considered were those that occurred after harvest and included peel discoloration, decay and shrivelling.

The experiment was terminated when the fruits reached VQR 5. Fruit peel at this stage is yellow, with discoloration (the protuberances turned black), and some with symptoms of fungal infection. At this stage, TSS, TA, and pH were determined. TSS was analyzed from the filtrate of homogenized 20 g fruit pulp of each sample with 100 mL distilled water using a blender. TSS of the filtrate was measured using the digital hand-held refractometer (Pocket PAL-1).

The filtrate obtained from the homogenization of fruit pulp was utilized in TA analysis. An aliquot of 10 mL from the filtrate suspension was dispensed into an Erlenmeyer flask with 20 mL distilled water. Two drops of phenolphthalein were added into each flask and titrated with standard NaOH (0.1 N) solution until the color of the extract was faint pink. The pH of the filtrate was measured using the Eutech Instruments pH 610 meter.

Pulp quality (color, consistency/softness, sweetness, sourness) and overall acceptability were evaluated by a panel of eight semi-trained judges. For pulp quality, a rating scale of 1 to 5, with 5 representing the most favorable response, was used. For overall acceptability, the hedonic rating of 9 (like extremely) to 1 (dislike extremely) was used.

The experiment was laid out in a completely randomized design (CRD) consisting of 3 replicates of 3 fruits per replicate per treatment. Analysis of variance (ANOVA) was performed using the GLM procedure of SAS v9.0. Differences between treatment means were compared using the least significant difference (LSD) test at 5% level.

RESULTS AND DISCUSSION

Respiration Rate

Biriba is a climacteric fruit as shown by the typical increases in CO_2 production regardless of storage temperature similar to those reported for *Annonas* (Biale and Barcus 1970; Alique et al. 1994; Jomngam et al. 2017). The climacteric maximum increased as the storage temperature increased from 13°C to ambient (29–31°C). Peak respiration of fruits stored at ambient was 54.7 mg CO_2 kg^{-1} h^{-1} and occurred at 6 d after harvest whereas in fruits stored at 20°C, peak respiration occurred on day 7 (Fig. 1A). Although peak respiration rate at 20°C was lower at 44 mg CO_2 $kg^{-1}h^{-1}$ than at ambient condition, the differences, however, were not significant. The respiratory rate of fruits stored at 13°C showed a gradual and slow rise, doubling the time to reach the highest peak

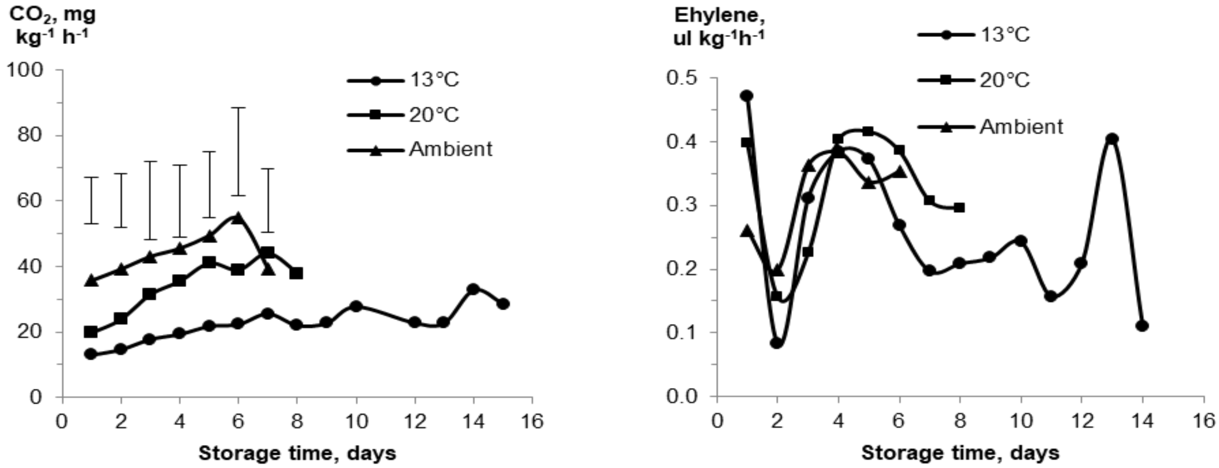

Fig. 1. Respiration rate (A) and ethylene production (B) of biriba fruits at varying storage temperatures. Vertical bars represent LSD values at 5% (n=3).

compared to that at ambient and at 20°C. Storing biriba fruits at 13°C significantly retarded respiration rate and delayed the onset of the respiratory rise by 9 d (Fig. 1A). From an initially low rate of 12.9 mg CO_2 $kg^{-1}h^{-1}$, it slowly increased during storage, reaching its first peak of 27.7 mg CO_2 $kg^{-1}h^{-1}$ on day 10 and the second peak of 32.8 mg CO_2 $kg^{-1}h^{-1}$ on day 14, followed by a decline. This second rise in respiration rate occurred toward the end of storage when fruits were already ripe and soft. Decay also started to set in at this stage. Differences in patterns of climacteric respiration in some *Annona* fruits have been reported. In this study on biriba, only one peak in respiration was observed when fruits were stored at ambient condition and at 20 °C similar to that reported by Brown et al. (1988) for sugar apple (*Annona squamosa*). At low temperature (13°C), however, a different response was obtained with two respiratory peaks occurring on the 10th and 14th days of storage. Brown et al. (1988) similarly reported two successive rises in respiration of custard apple (*Annona reticulata*) and cherimoya (*Annona cherimola* Mill.) fruits. Custard apple fruits stored at 25°C and 20°C had a clear climacteric peak whereas those stored at 15°C and 10°C did not show any distinct rise in respiration rate (Vishnu Prasanna et al. 2000).

Ethylene Production

Unlike respiration rate which started with low CO_2 production 24 h after harvest, a very high level of C_2H_4 was measured on day 1 of storage at all temperatures with the highest value of 0.472 μL $kg^{-1}h^{-1}$ obtained in fruits stored at 13°C. This high C_2H_4 production was followed by a drastic decline on day 2 (Fig. 1B). In soursop (*Annona muricata* L.), Bruinsma and Paull (1984) reported that the climacteric rise normally encountered in fruit with autocatalytic ethylene production was preceded by a harvest-induced transient respiratory rise. In the case of this experiment in biriba, it was ethylene production that exhibited a transient rise which can be attributed to the stress induced by detachment of fruit from the tree.

On the 2nd day, an abrupt decline was observed at all storage temperatures followed by the typical rise in C_2H_4 production of fruits that were starting to ripen. Peak ethylene production at ambient condition occurred on the 4th day at 0.384 μL $kg^{-1}h^{-1}$ while it was on the 5th day at 20°C that a peak production of 0.416 μL $kg^{-1}h^{-1}$ occurred. Peak ethylene production of biriba at ambient coincided with climacteric peak occurring at the ripe stage. At 20°C storage, however, peak ethylene production occurred 2 d prior to the climacteric peak. Rise in ethylene production on day 4 at 13°C storage did not coincide with a rise in respiration and this was followed by an abrupt decline to a low level of 0.157 μL $kg^{-1}h^{-1}$ on day 11. The second peak in C_2H_4 production occurred on day 3 which was 1 d ahead of the second rise in respiration (Fig. 1A and 1B).

The decrease in respiration rate and ethylene production at 13°C also corresponded to a storage life extension of biriba fruits to 15 d. Fruits stored at ambient and 20°C lasted only 5 and 8 d, respectively. A two-fold increase in the ripening period of cherimoya was also attributed to the delay in ethylene production at 10°C (Lahoz et al. 1993).

Fruit Firmness

Fruit firmness decreased during storage for all temperatures and the higher the storage temperature, the earlier was the onset of firmness loss (Fig. 2). Fruits stored at ambient and 20°C started to soften on days 3 and 5,

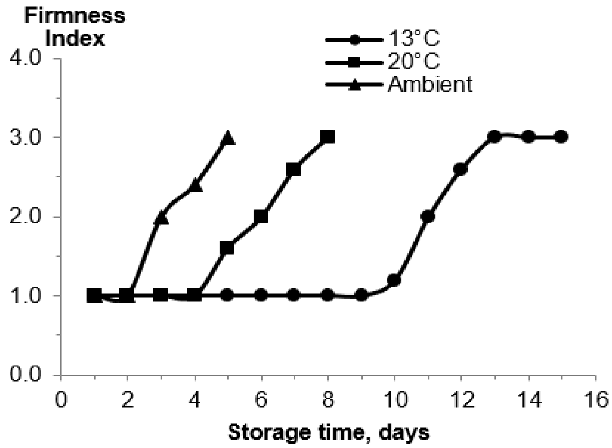

Fig. 2. Firmness of biriba fruits at different storage temperatures. Each point is an average of 10 fruits. Rating scale: 1- firm; 2-yielding; 3-soft; 4-very soft.

respectively, and softening progressed rapidly thereafter. Onset of softening for fruits stored at 13°C took 10 d and similarly progressed rapidly thereafter. Similarly, firmness in atemoya fruits was highest at 15°C compared with fruits stored at 20, 25, and 30°C. The decline was gradual in contrast to a rapid decline observed at higher temperatures (Jomngam et al. 2017).

Ripening in biriba fruits is indicated by softening. The loss in firmness begins during the onset of respiratory climacteric and the rise in ethylene production for fruits stored at ambient condition and at 20°C. The same pattern of firmness loss in cherimoya was reported by Alique et al. (1994). At 13°C, the rise in ethylene production on day 4 did not coincide with a rise in respiration nor did it initiate ripening as indicated by the retention of fruit firmness. Fruits, however, lost firmness and ripened during the second rise in ethylene production. This slow response to ethylene at low temperature may be responsible for the three-fold increase in the ripening period. It showed that storage temperature altered the respiration and ethylene production patterns in biriba fruits.

The onset of ripening and softening in biriba fruits rendered them susceptible to pathogens that could have penetrated the stems or wounds in the peel that are hardly visible, and eventually affected the quality of the fruit pulp. Proliferation of these pathogens is usually favored at higher temperatures such that deterioration of the fruit is also hastened.

Moisture Loss

Storage at low temperature considerably reduced the amount of water lost from biriba fruits (Fig. 3). Cumulative moisture loss at 20°C and ambient reached 9.5% on the 7th day of storage, which was twice as much compared with the water lost at 13°C for the same period. Moisture loss increased linearly with storage time at each temperature with the lowest rate of increase observed at 13°C storage.

Fruits stored at higher temperatures lost more moisture which could be attributed to higher transpiration (Xanthopoulus et al. 2017) and respiration as reported in custard apple (Vishnu Prassana et al. 2000). Slowing down of these two processes could be one of the reasons for the observed lower weight loss at 13°C.

Visual Quality Rating (VQR)

Visual quality rating of the fruits declined during storage at all temperatures (Fig. 4). The higher the storage temperature, the faster is the decline in visual quality, taking only 3 and 5 d at ambient condition and at 20°C, respectively. Even before the fruits ripened, visual quality already started to decline due to discoloration. Fruits stored at 13°C took 12 d to reach a VQR of 5. Other defects such as symptoms of decay were observed especially on fruits stored at ambient and at 20°C.

Moisture loss is probably one of the reasons for the loss in quality of the produce. A significantly high correlation between water loss and visual quality was found in other fruits and vegetables (Nunes and Emond 2007). In litchi (*Litchi chinensis* Sonn) fruits, for instance, water loss caused rapid skin browning that rendered the fruits commercially unacceptable for marketing (Jiang and Fu 1999).

Quality deterioration in biriba fruits in terms of appearance is largely due to peel discoloration

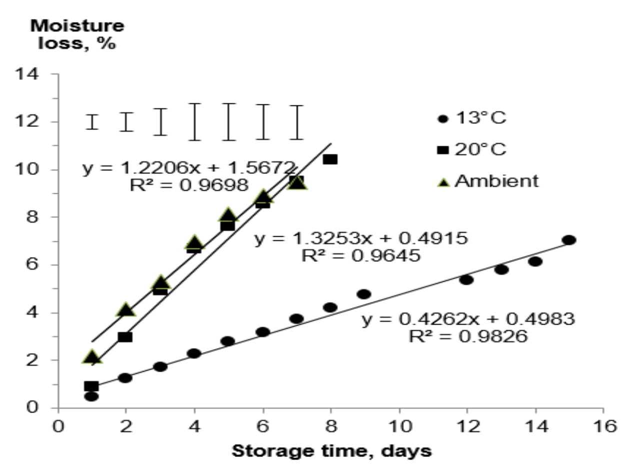

Fig. 3. Moisture loss in biriba fruits under varying storage temperatures. Vertical bars represent LSD values at 5% (n=3).

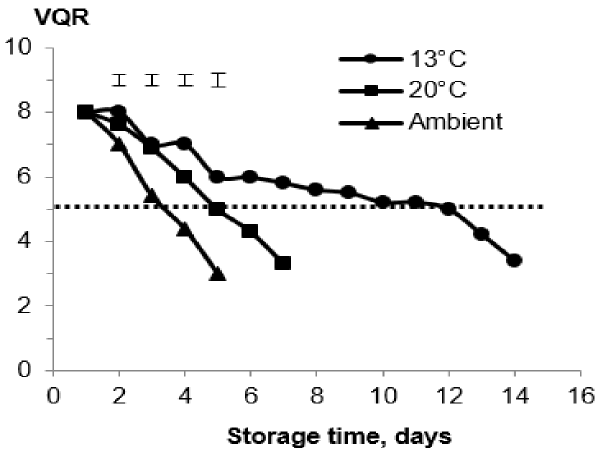

Fig. 4. Visual Quality Rating (VQR) of biriba fruits under varying storage temperatures. Vertical bars represent LSD at 5% (n=10). Rating scale: 9=Excellent, field fresh and 1=Non-edible. Dotted horizontal line indicates limit of marketability

characterized by blackening of the protuberances (Fig. 5). Browning of protuberances brought about by oxidation of polyphenols with the increased activity of polyphenol oxidase is one of the important oxidative reactions in cherimoya fruits leading to loss of visual quality and limiting marketability (Martinez et al. 1993).

Optimum storage temperature of a close relative of biriba, the atemoya (*Annona cherimola* Mill. × *A. squamosa* L.), and cherimoya was reported to be 13–16°C (George and Nissen 1993) at which fruits can be stored for 2 wk with minimum loss of quality. Visual quality of atemoya 'African Pride' started to decline after 6 d of storage at 12°C (Batten 1990). Atemoya stored at 15°C retained its good quality for 17 d (Yamashita et al. 2002).

Water loss is generally considered a form of stress that can cause an increase in ethylene synthesis affecting the ripening process and senescence. Longer quality maintenance at lower temperature storage is likely due partially to alleviation in water stress.

TSS, TA, and *pH*

From an initially low (6.1 °Brix) TSS content of fruits at the unripe stage, it increased to about 15 °Brix at the ripe

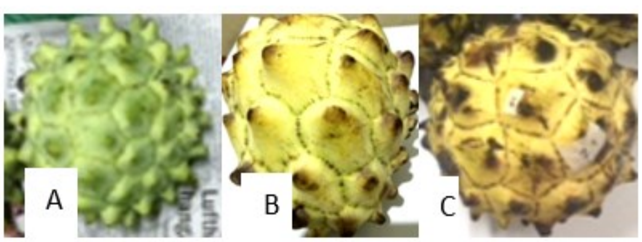

Fig. 5. Appearance of biriba fruits at the unripe (green) stage, ripe (yellow) stage and at the limit of marketability (VQR 5).

stage (Table 1). On the other hand, TA increased during storage, concomitant with a decrease in pH, indicating that fruits became slightly acidic. This result is in agreement with the observation in cherimoyas having the same TSS for fruits ripened at 22°C for 4 d and at 12°C for 10 d (Gutierrez et al. 1994).

Sensory Ratings

Sensory evaluation of the pulp, which was done when fruits reached VQR 5 (limit of marketability), showed significant differences in color and sourness (Table 2). Pulp color was off-white at all storage temperatures but fruits stored at ambient and 13°C had traces of light brown. The less uniform pulp color could be due to the effect of fungal infection in the peel that could have slightly penetrated and affected the pulp color at ambient storage. The traces of light brown observed in fruits at 13°C could be an indication of early symptoms of chilling injury. Some chilling injury symptoms of tropical and subtropical fruits include internal discoloration observed in avocados and subepidermal brown streaking of vascular tissues in bananas (Souza and Drew 2010).

Slightly perceptible sourness was detected in fruits at 13°C but none at the other temperatures. Sweetness, consistency, and overall acceptability rating of pulp quality were similar at all temperature regimes at the end of the storage period.

CONCLUSION

Storage temperature affected the postharvest behavior of biriba fruits. Respiration rate, ethylene production, and moisture loss were higher at ambient condition and at 20°C than at 13°C, resulting in faster fruit ripening, softening and decline in visual quality. The high moisture loss at high temperature resulted in fast quality decline as exhibited by the discoloration of the protuberances. Generally, storage temperature did not affect the TSS, TA and pH of the fruits at the ripe stage. Though slight differences in pulp color and sourness were observed, overall pulp acceptability was similarly not affected.

Table 1. Total soluble solids (TSS) content, titratable acidity (TA) and pH of biriba fruits at the limit of marketability.*

Storage Temp. (ºC)	TSS (ºBrix)	TA (%)	pH
Initial	6.1	0.29	5.6
13	15.3a	0.81a	4.02b
20	15.8a	0.81a	4.12a
Ambient (29-31)	15.7a	0.81a	4.10a

*In a column, means followed by the same letter are not significantly different at 5% level, LSD.

Table 2. Pulp quality of biriba fruits after storage at varying temperatures taken at VQR 5*.

Characteristic	Storage Temperature (ºC)		
	13	20	Ambient (29-31)
Color	2.6 b	3.0b a	2.5 b
Sweetness	3.1 a	2.8 a	2.6 a
Sourness	2.2 a	1.2 b	1.4 b
Consistency	3.8 a	3.5 a	3.5 a
Overall acceptability	4.7 a	5.5 a	4.9 a

*In a row, means followed by a common letter are not significantly different (P<0.05) using LSD.

Scale used: Color: 1 = light brown, 2 = off-white with light brown traces, 3 = off-white, 4 = white with off-white traces, 5 = white; **Aroma, Sweetness, Sourness**: 1 = not perceptible, 2 = slightly perceptible, 3 = moderately perceptible, 4 = definite, 5 = highly perceptible; Consistency: 1 = hard/firm, 2 = more firm than soft, 3 = soft but with firm or hardened portions, 4 = soft with watery portions, 5 = uniform softness; **Overall acceptability**: 1 = dislike very much, 2 = dislike, 3 = dislike slightly, 4 = neither like nor dislike, 5 = like slightly, 6 = like, 7 = like very much.

Fruits stored at ambient condition lasted only for 5 d while those stored at 20°C lasted for 8 d; 20°C is the usual temperature in retail displays in supermarkets. Storage at 13°C maintained the acceptable quality attributes of the pulp for up to 15 d.

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