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Yellowing of Frozen Acerola (*Malpighia emarginata*) Fruit

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Abstract. Experiments were carried out using the facilities and equipment of MAISA, a commercial producing company in Mossoró, Rio Grande do Norte state, Brazil. After harvest and selection according to the procedures used by the company, fruits were either pre-cooled or not, frozen in room (- 18C) or liquid nitrogen tunnel and stored under three different conditions: freezer, room and container, the last two commercially in use by the company. Frozen fruits were packed in 500 g bags, arranged in commercial 18 kg boxes for frozen acerola and stored for 80 days. Fruits were evaluated every 10 days as for the appearance of yellow fruits, soluble solids, pH, acidity and vitamin C. The best results, i.e. longer lasting of red color, were got when fruits were stored in freezer or container, where temperature was kept more stable, whether of not pre-cooling was used or which was the freezing method.

Resumen. Fueron desarrollados experimentos utilizando las instalaciones y equipos de la Mossoró Agroindustrial S.A. - MAISA, empresa del estado del Rio Grande do Norte, Brasil. Después la cosecha y selección hechas acuerdo a los procedimientos usuales de la empresa, los frutos fueron pre-resfriados o no, según el tratamiento, congelados en camara (-18C) o túnel de nitrógeno líquido y almacenado en tres diferentes condiciones: freezer, camara y container, los dos últimos utilizados comercialmente por la empresa. Los frutos fueron embalados en bolsa de 500g, despuestos en cajas de comercialización de 18 Kg y almacenados por 80 días. Fueron hechas evaluaciones en cada 10 días de aparecimiento de frutos amarillos, sólidos solubles, pH, acidez y vitamina C. Los mejores resultados, es decir, manutención más prolongada de la color roja, fueron obtenidas cuando los frutos fueron almacenados en freezer o container, donde la temperatura fue mantenida más estable independente del empleo o no de pre-resfriamiento o del método de congelación.

Acerola belongs to the Malpighiaceae, originating in Tropical America (Knight, 1980) and became of worldwide importance after Asenjo and Freire (1946) discovered the high vitamin C content of its fruit. For this reason it is presently considered as one of the most important natural sources of that vitamin, which is comparable only to what is found in an Amazonian native fruit called camu-camu [*Myrciaria dubia (H.*B.K.) McVaugh.](Andrade,1991), and is more than ten times as high as in citrus fruits, traditionally taken as rich sources of vitamin C (Alves,1993). Commercial prodcution of acerola has developed in some tropical and subtropical regions within the American continent and only in the last decade has achieved the status of commercial orchard in Brazil, due to the increasing demand of export market (Alves,1992).

Brazil is among the most important producers of this fruit. There are many plantations in the country that in the 1980s was aimed at the export to Europe, Japan and United States, but today supplies mainly internal demand (Alves, 1996). The crop has currently been shown to be profitable; many products such as pulp, yogurt, frozen fruit or juice, vitamin C capsules are found on the market in all parts of Brazil with high level of acceptance by consumers. Fruit is usually sold in frozen state or as processed products, fresh fruit being limited to local markets within producing regions due to its high perishability either at ambient temperature or under refrigeration (Alves, 1993; Alves et al., 1995). Despite techniques for freezing and storage of frozen products, acerola has great losses due to color changes. To diagnose the problems found in freezing and storing frozen acerola and especially the yellowing of fruits, a series of experiments were carried out simulating the procedures adopted by a commercial company.

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Materials and Methods

The experiments were carried out using the fittings and equipment of MAISA - Mossoró Agroindustrial S.A., a company located in Mossoró, state of Rio Grande do Norte, Brazil. Fruits were harvested and selected according to the procedures used by the company. In experiment I, fruits were either pre-cooled or not, submitted to slow room freezing and stored in three different conditions: freezing room, domestic freezer or container. In experiment II fruits were submitted to fast freezing in a liquid nitrogen tunnel. Pre-cooling was done in the washing tank, that was fitted with a water cooling system. The mean temperature of acerola coming from the field was around 30°C and dropped to 20°C after 5 minutes of pre-cooling with the 15°C washing water . Fruits not pre-cooled were washed with water at ambient temperature (30°C) for 5 seconds.

The time required for freezing was 24 hours in the freezing room at -15°C, and 8 min in the tunnel with liquid nitrogen at -72°C and a speed of 0.5 m/minute. Frozen fruit were packed in polyethylene thermoplastic sealable bags by means of an automatic packing machine, arranged in 16 kg (or 32 bags) boxes and stored for 80 days. Fruits stored in the domestic freezer were not put in boxes. The storage temperature was recorded throughout the experiment for all of the storage conditions. Fruits were evaluated every 10 days for the following characteristics: color, total soluble solids (SS), total titratable acidity (TA) and vitamin C. Color was evaluated by counting of yellow and red fruits per 500 g bag. The results were transformed in % of yellow fruits and % of red fruits. Scores were defined together with the company that took into account the % of yellow fruits per 500 g bag as follows: 0 = 0 to 5%- very good; 1 = 5 to 10% - acceptable; 2 = 10 to 20%- not bad; 3 = 20 to 30%- bad; 4 = > 30%- very bad.

Soluble solids (SS) was measured with a refractometer and expressed in ∘Brix as recommended by AOAC (1992). Titratable acidity (TA) was determined by titration with diluted NaOH, as recommended by IAL (1985). Results were expressed percentage of malic acid. pH - measured by potenciometry using glass electrode, according to AOAC (1992). Results expressed in pH units. Total vitamin C content was determined by titration with 2,6 dichloro phenolindophenol, as described by Strohecker *et al.* (1967). Results were expressed as milligrams per 100 grams. Four bags (repetitions) were used for each evaluation, and vitamin C was evaluated only after 0, 20, 40, 70 and 80 days in storage.

Results and Discussion

The longest lasting red color were attained when fruits were store in domestic freezer or container (Figure 1), where temperatures were kept more stable. Pre-cooling was important to keep fruit color after slow freezing and container storage, that allowed more air circulation. The most important physical changes that happen during the freezing process was re-crystallization. This was drastic and may continue during storage (Bernhardt et al., 1979; Reid, 1983). This phenomenon is caused mainly by temperature fluctuations in the storage room where fruits were kept in good condition for not more than 40 days. Since the same room was used for both freezing and storage, a problem was caused by frequently opening the doors and entrance of hot product, as it was shown by the temperature records. Temperature fluctuations favor the growth of large ice crystals at the expenses of smaller ones, caused by the water vapor pressure differences between them, a process which is called re-crystallization (Bernhardt et al., 1979; Heldman, 1983; Neves Filho, 1991). Crystal growth may cause cell disruption provoking changes in texture and biochemical composition, the last leading to fruit yellowing.

Fruit composition in general was little affected by freezing and storage procedures (Figures 2 and 3). Soluble solids content and titratable acidity however were affected by storage time (Figure 2A and C). Slow freezing also leads to crystallization and in this case, during a critical phase while product is not completely frozen, fermentation may occur and cause the amount of soluble solids to decrease, since they are composed mainly of sugars and acids. This was significantly less important when fast freezing (liquid nitrogen) was used, confirming what was previously discussed.

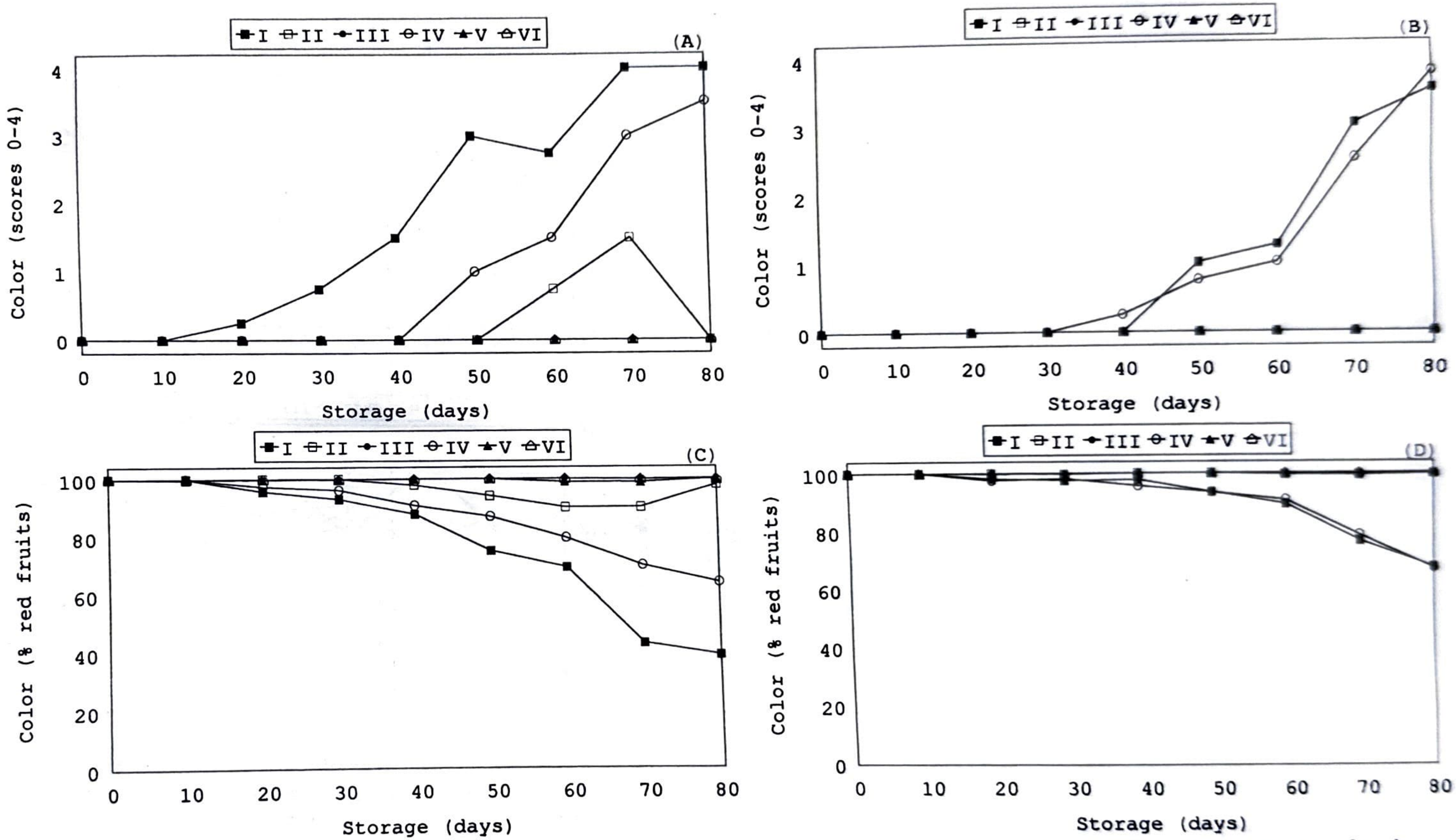

Figure 1. Color of frozen acerola pre-cooled (A and C) or not (b and D) and submitted to different freezing and storage conditions. (I = slow freezing and freezing room storage; II =s low freezing and container storage; III = slow freezing and domestic freezer storage; IV = fast freezing and freezing room storage; V = fast freezing and container storage; VI = fast freezing and domestic freezer storage).

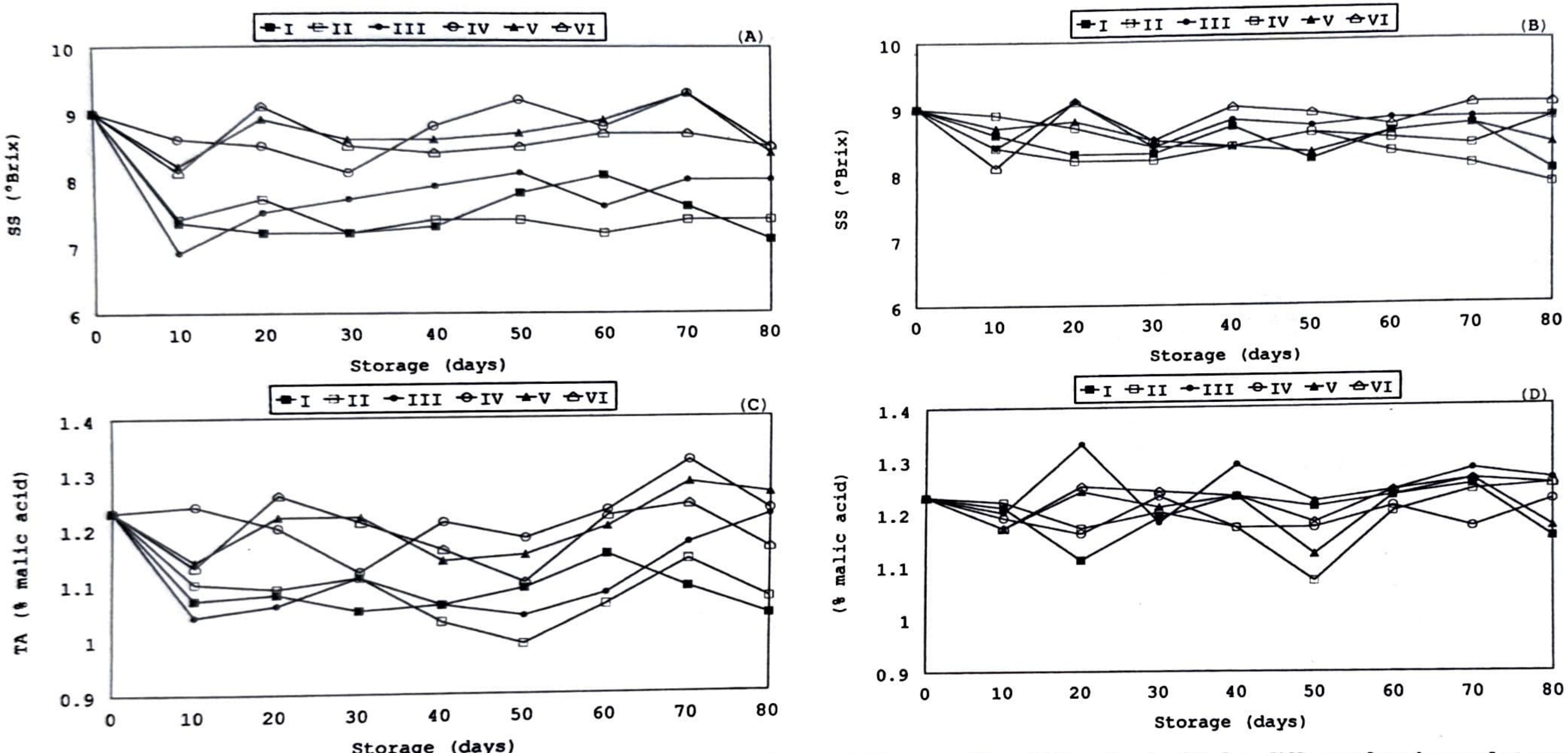

Figure 2. Soluble solids and titratable acidity of frozen acerola pre-cooled (A and C) or not (B and D) and submitted to different freezing and storage conditions. (I = slow freezing and freezing room storage;II =slow freezing and container storage; III = slow freezing and domestic freezer storage; IV = fast freezing and freezing room storage; V = fast freezing and container storage; VI = fast freezing and domestic freezer storage).

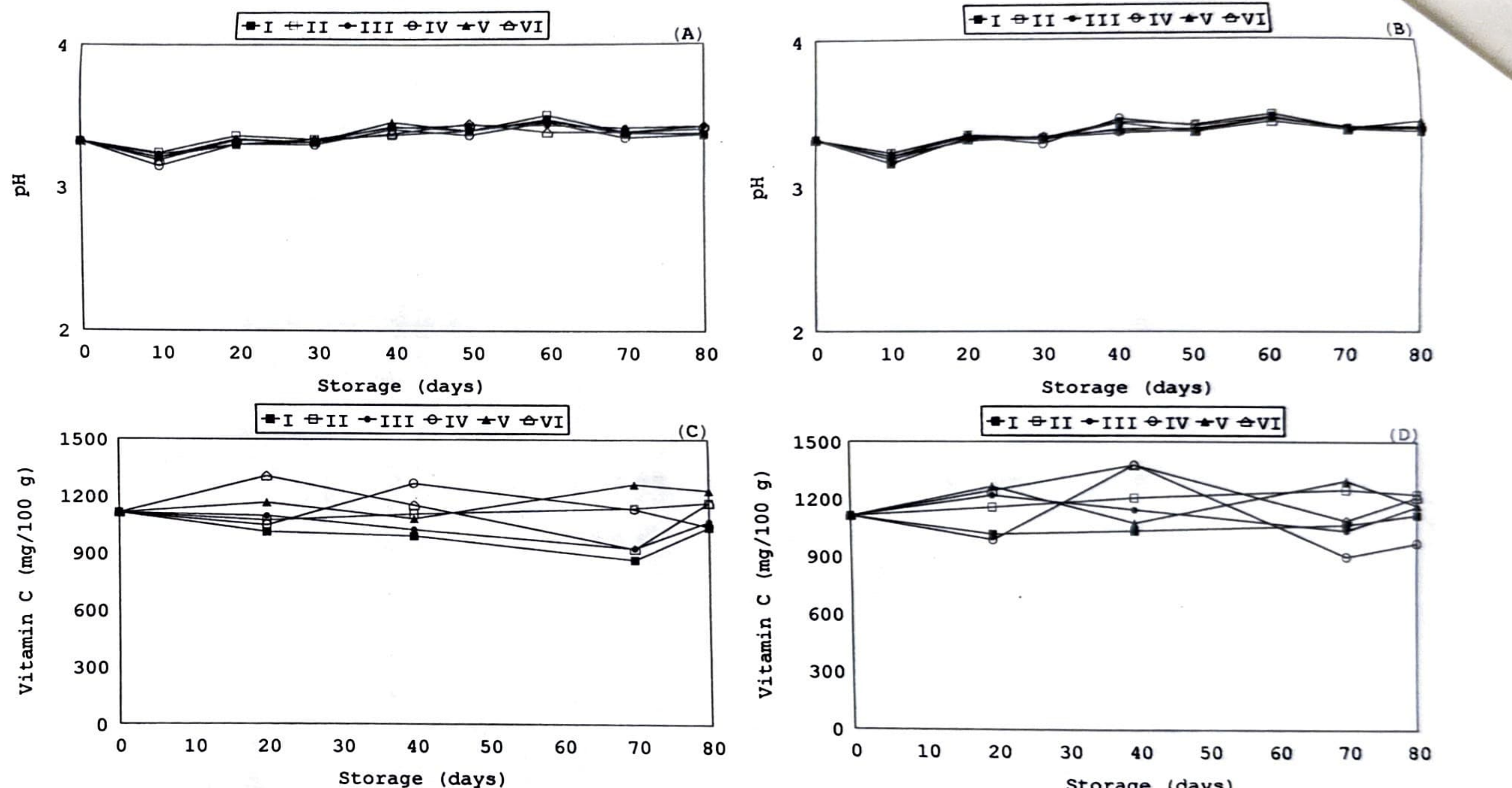

Figure 3. pH and vitamin C of frozen acerola pre-cooled (A and C) or not (b and D) and submitted to different freezing and storage conditions. (I = slow freezing and freezing room storage; II =s low freezing and container storage; III = slow freezing and domestic freezer storage; IV = fast freezing and freezing room storage; V = fast freezing and container storage; VI = fast freezing and domestic freezer storage).

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