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RELATIONSHIP BETWEEN PEEL COLOR AND FRUIT QUALITY OF PAPAYA (*CARICA PAPAYA* L.) HARVESTED AT DIFFERENT MATURITY STAGES

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Abstract. **The development of papaya (*Carica papaya* L.) fruit cv. Improved Sunrise Solo Line 72/12, grown in Espírito Santo, Brazil, was studied. At 110 days after anthesis (DAA) fruit reached their maximum size in terms of length and diameter. The fresh weight increased exponentially until 120-130 DAA, when fruit reached 50% of their final dry weight. After 120 DAA through completion of development there was an intense accumulation of dry matter. Total soluble solids were low until about 120 DAA, but thereafter increased sharply through ripening. Peel color presented a dark green color until 100-110 DAA, changing to light green between 120-140 DAA, which corresponded to the phase of intense accumulation of dry matter and total soluble solids. The first yellow string became visible on the fruit surface at 145-160 DAA. Seeds presented faster color changes than did the peel. At 90 DAA seeds began to get dark. At 110 DAA this process was intensified and at 140 DAA seeds became ripe, reaching their final black color. Once the major accumulation of total soluble solids and dry matter has occurred after 120 DAA, and papaya fruit does not accumulate starch, commercial fruit quality is guaranteed if fruit are harvested at 145 DAA, when the first yellow string appears in the peel and seeds turn black. However, since at 120 DAA peel color turns from dark to light green and seeds are gray, it may be possible that fruit are entering the climacteric phase. Therefore, it remains to be evaluated whether fruit at 120 DAA can be harvested and induced to ripen by ethylene treatment.**

Brazil is the major papaya grower in the world (FAO, 1994). In 1993, this country was responsible for more than 30% (ca. 1.7 million tons) of world total production (IBRAF, 1993). Despite that, there are several aspects concerning fruit physiology which have to be studied to guarantee fruit quality. Fruit developmental stage at harvest affects quality and post-harvest life. Brazilian growers harvest papaya fruit after the first yellow string appears in the peel. External color has traditionally been used as a maturity index for papayas (Akamine and Goo, 1971). Although in many cases peel color correlates with fruit maturity, the skin color of papayas under field conditions is, generally, a subjective judgment (Peleg and Gómez Brito, 1975) which can lead to the harvesting of immature fruits. Efforts have been made to objectively measure fruit maturity using non-destructive techniques (Paull, 1993). Delayed light emission (Forbus et al., 1987; Forbus and Chan, 1989), transmission spectroscopy at three wavelengths (Birth et al., 1984) and reflectance measurements (Couey and Hayes, 1986) have been evaluated. But these technologies are still not practical for application in Brazilian orchards for economic reasons.

In the present work we analyzed peel and seed color, fruit size and total soluble solids content during fruit development, in order to address whether the current parameters used to indicate harvest point guarantee that fruit have reached appropriate stage of development and maturity, such that acceptable quality is guaranteed. We also investigated some additional characteristics which may help in determining these features. Such knowledge would assist papaya growers in planning harvests resulting in higher fruit quality and extended shelf life.

Material and Methods

Plant material: Papaya (*Carica papaya* L.) cv. Improved Sunrise Solo Line 72/12 fruit were harvested at Sooretama Research Station, Linhares, Espírito Santo, Brazil, from August 1995 to February 1996. Plants were treated according to standard practices recommended for quality fruits destined for export, including sprinkler irrigation. Hermaphrodite flowers in excess were tagged at blossom, and one marked fruit was kept for each leaf axilla. Anthesis was considered the moment that flowers were partially opened, prior to indications of senescence. The day of tagging was considered as the date of anthesis.

Chemical and physical analyses: Length and diameter, fresh and dry weight, and total soluble solids of ten individual fruits were determined weekly until fruits were ripened. Each fruit represented a replication. From 28 days after anthesis (DAA) to 84 DAA, these parameters were analyzed every two weeks. After harvest, fruit were wrapped in humid absorbent paper, stored in boxes for 16 h prior to analysis. Length was considered the measurement between peduncle insertion and stigma cicatrix. Diameter was measured in the equatorial region. For the fresh matter measurement whole fruit was weighed. For dry matter calculation seeds and pulp were separately dried in an 80°C forced air oven, and then weighed. Percentage of soluble solids from the pulp was determined by using an Abbe refractometer at 25°C. Six cylinders, 5 mm diameter each, from the pulp without skin were extracted from the fruit equator, using a cork borer. Juice was extracted using a hand press. Changes in peel coloration were rated according to a visual scale, built in comparison to Munsell

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(1929) Color Chart. Similar colors were grouped in grades i.e. 0 = green-yellowish; 1 = light-green; 2 = green; 3 = dark-green; 4 = color break (peel turning from dark to light green, without yellow string); 5 = first yellow string incipient; 6 = one very perceptible yellow string; 7 = three (or more) visible strings; 8 = more yellow than green. Seed coloration was also determined visually, according to a visual scale: 1 = green/yellowish transparent; 2 = white; 3 = white/light-grayish with white integument and yellow embryo; 4 = light-gray with brown integument and hard embryo; 5 = gray-yellowish with brown-reddish integument; 6 = gray-brownish with dark-brown integument and incipient sarcotesta; 7 = black-brownish with formed sarcotesta; 8 = black with yellowish sarcotesta.

Experimental design: Experiment was conducted in a complete random design. Curves in Figures were obtained by linear regression analysis.

Results and Discussion

Papaya fruits showed a single sigmoid growth curve based on changes of fruit length and diameter (Fig. 1). Fruit exhibited a fast phase of growth in the earlier stages after anthesis, reaching maximum size by 110 DAA. The exponential phase of growth was then followed by a stable phase, without apparent change in dimension (Fig. 1) until 168 DAA, when fruit were fully ripened. Silva (1995) found the same kind of single sigmoid curve for papaya cv. Sunrise Solo, whereas Ghanta (1994) observed a double sigmoid curve for papaya cv. Ranchi. These differences in growth curves may be due to sampling errors, cultivar differences, or different cultural conditions (Walton and De Jong, 1990). The pattern of fruit weight was similar to that of length and diameter, but the maximum fresh weight was reached 120-130 DAA (Fig. 2).

Fruit dry weight followed an exponential curve (Fig. 2). At 120-130 DAA, 50% of fruit dry matter was formed (Fig. 2).

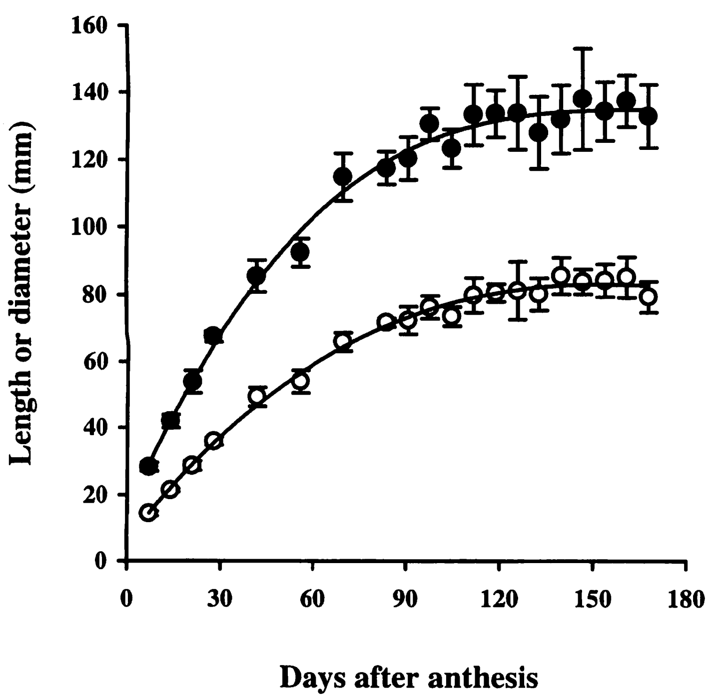

Figure 1. Papaya fruit length (filled circles) and diameter (open circles) throughout development.

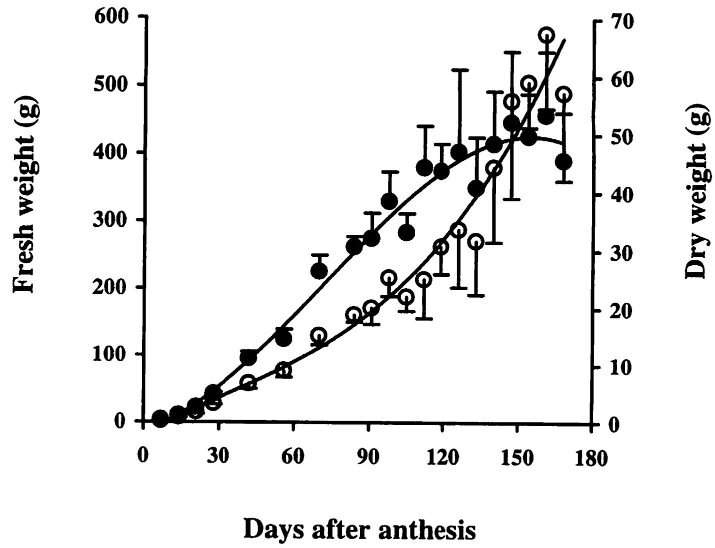

Figure 2. Papaya fruit fresh (filled circles) and dry weight (open circles) throughout development.

From anthesis to 120-130 DAA fruit undergo an exponential increase in size (Fig. 1) and fresh weight (Fig. 2), and the accumulation of dry matter appears to be mainly related to increases in cell wall volume due to cell divisions and parenchyma cell expansion (Roth and Clausnitzer, 1972). Fruit accumulated 50% of their dry matter between 120 and 168 DAA, an interval which corresponds to less than a third of the time required for complete fruit development. Qiu et al. (1995) also observed that dry weight increase in papaya cv. Kapoho Solo occurred at a higher rate just after maturity, 130 days postanthesis. After 120-130 DAA fruit growth stops (Fig. 1 and 2), and dry matter accumulation continues. This may be mainly due to photossyntates, directed mostly to the pulp.

Peel color began to get darker as the developed ovary began to increase in size (Fig. 3), changing from index 0 to 2

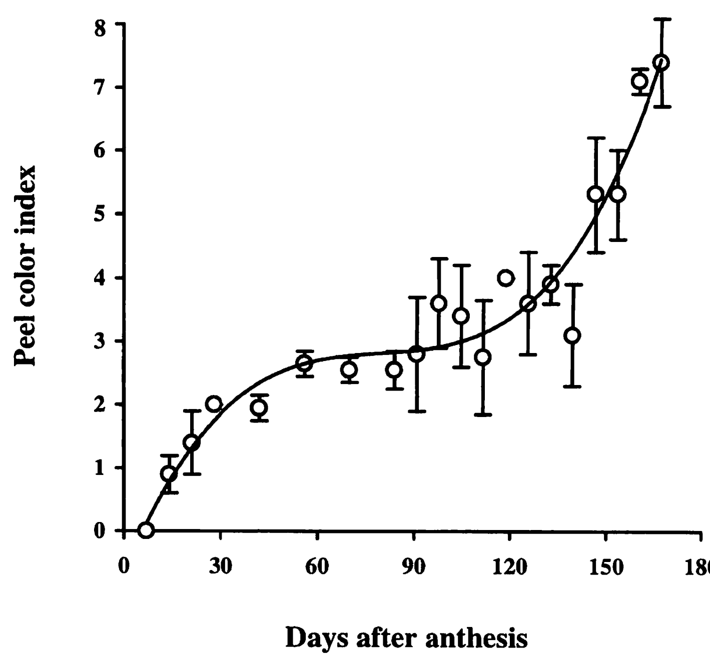

Figure 3. Peel color index in developing papaya fruit.

(green color) until 30 DAA. At 60 DAA it reached index 3 (dark green coloration) and remained dark green until 120 DAA. Dark green peel is associated with fruits still increasing in size (Fig. 1), indicating that they are possibly still immature. Between 120 to 140 DAA, when fruit growth stopped, the peel reached the color-break stage (Index 4, Fig. 3), which is very difficult to be distinguished under field conditions, and indicates proximity to the climacteric peak. The changing in fruit color from dark to light green, without any yellow string is considered mature green by Marin et al. (1995) and Chan (1991). Because the external green appearance of both immature and mature green fruit are indistinguishable by visual examination (Birth et al., 1984), it is risky to harvest fruit that do not show any sign of yellow coloration in the peel. The higher the percentage of yellow in papaya fruit peel at harvest, the higher the pulp quality after ripening (Thompson and Lee, 1971). On the other hand, the greener the peel at harvest, the longer the postharvest life. The first yellow string appeared in fruit surface by 145 DAA (Fig. 3). This is the current harvest index in Brazil to the point of 6% of yellow on the surface (Birth et al., 1984; Akamine and Goo, 1971). Fruit surface was predominantly yellow by 160 DAA, indicating completion of fruit ripening.

Seed coloration changed faster than did coloration in the peel. After 90 DAA, seeds began to darken slightly, which was intensified at 110 DAA, when embryo became hard, integument darkened and seeds became light-gray (Fig. 4). After 110 DAA seed initiated an intense darkening until 140 DAA when all seeds were mature, as judged by their dark-gray or black coloration (Fig. 4) and by the presence of sarcotesta (Paull, 1993). Interestingly, the complete darkening of seeds at 140 DAA coincided with peel color turning to light green (Index 4). As already pointed out, at that time fruits seemed to have reached physiological maturity, but did not yet exhibit a yellow string in the peel. Perhaps it is similar to Solo papayas, which start seed color changes at 110 DAA, followed by peel color yellowing only 20 days later (Chan et al., 1979; Birth et al., 1984). Therefore, it could be possible to utilize this variable to indicate an earlier harvest index.

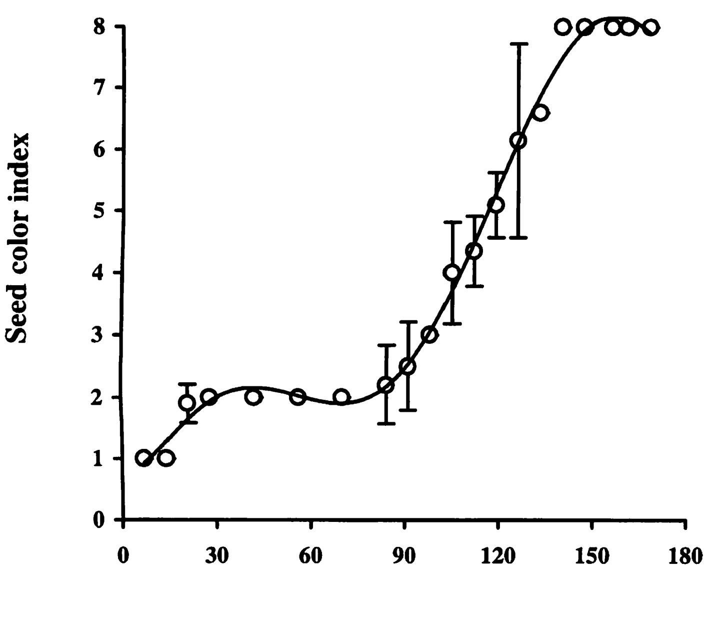

Figure 4. Seed color index in developing papaya fruit.

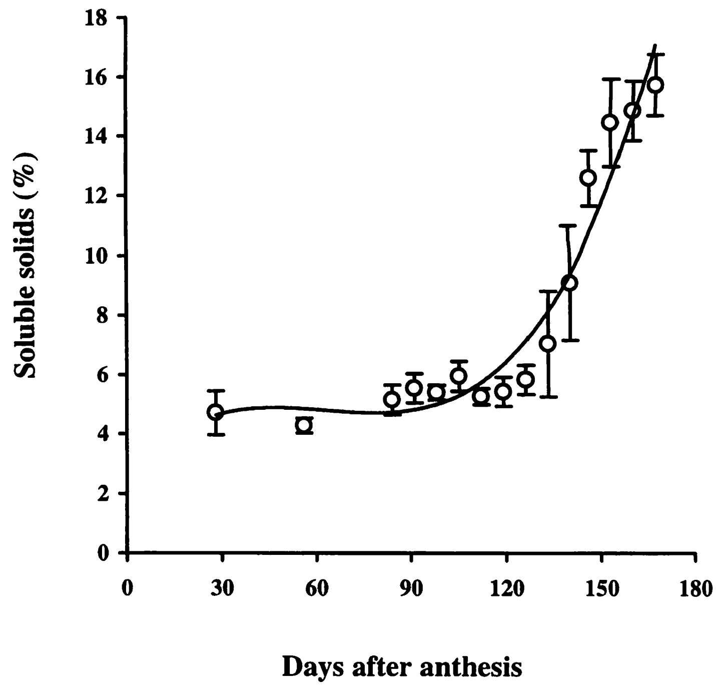

Figure 5. Pulp total soluble solids content throughout papaya fruit development.

From the beginning of growth until 120 DAA, total soluble solids (TSS) content remained ca. 4.5 to 5.0% (Fig. 5) probably because in this period of time tissues expanded intensively, as depicted by increase in dimensions (Fig. 1) and fresh weight (Fig. 2). At 120 DAA, TSS started increasing (Fig. 5), coinciding with the start of color break stage (Fig. 3), and the ending of fruit growth (Fig. 1 and 2) and seed maturation (Fig. 4). At 145 DAA, when the first yellow string appeared in the peel (Fig. 3), TSS doubled the initial content, obtaining close to the minimal percentage required commercially. This information confirms that fruit should have at least 6% surface yellow coloration to meet the minimum TSS of 11.5%, required by Hawaiian grade standards for marketable papayas (Akamine and Goo, 1971). At the end of fruit development (168 DAA), fruits reach a TSS of 15%. Based on changes in TSS content, harvest should take place at 145 DAA, when skin starts yellowing (Fig. 3). At 120 DAA, when, based on fruit size and seed coloration, we thought that fruit might be physiologically mature, TSS content was only 6%, and therefore, fruit harvested at that time may not ripen properly and may not reach minimal quality standards. The possibility of starch conversion to sugar after the fruit is detached from the tree is not possible because papaya fruit do not accumulate starch during development (Selvaraj and Pal, 1982; Selvaraj et al., 1982). However, considering the advantages to harvesting 120 DAA fruits in terms of reduced mechanical injuries and increased postharvest life, it would be interesting to test how fruit harvested at this stage behave after ethylene application.

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EFFECT OF CHEMICAL TREATMENT ON LIVESTOCK FEED VALUE OF MUSCADINE POMACE

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Abstract. **Research has been performed for several years on improving feed quality of food processing waste materials. Muscadine (*Vitis rotundifolia*) waste, specifically grape pomace, was examined in this work for its potential animal feed usage. Many treatments were attempted, including sodium and calcium hydroxide. Samples of muscadine pomace were exposed for various times (24, 48, and 72 hrs) at various concentrations (e.g. 2%, 3%, and 5% for NaOH) of these chemicals. Low concentration sodium hydroxide with short (24 hrs) exposure time showed the most promise thus far. Results indicate improvements of approximately 50% *in Vitro* Organic Matter Digestibility over untreated pomace. Digestibility increases were less pronounced (20%) when exposure times were 72 hours. When a larger scale experiment was performed, the improvements were not as significant. These results suggest that muscadine pomace could be a potentially useful cattle feed source.**

Introduction

Solutions to waste problems are vital when one considers the closing of landfills, waste incineration disputes, waste disposal crisis, etc. Wastes, instead of being discarded, in most cases could be used in some productive manner. One type of waste generated is agricultural waste, which provides possibilities of use as animal feed. Significant quantities of by-products are produced as a result of grape processing. Over 50% of the fruit constitutes waste material when juice is squeezed from grapes for wine, juice, and other processed products. Utilization of grape waste as feed material has the overall industry-wide potential (in the U.S.) of generating an additional ~$250 million profits opposed to a landfill cost of ~$25 million. In this work, the waste generated by growing and processing muscadine grapes will be discussed.

Muscadine (*Vitis rotundifolia* Michx.) is a type of grape that grows especially well in the southeastern United States. As the large majority of grapes grown internationally belong to either the *vinifera* or *labrusca* species, little previous work has been done on investigating grape muscadine wastes as potential animal feeds. Nonetheless, as the muscadine grape in-