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Note

Shape changes of longan fruits during growth in a tropical environment

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A b s t r a c t. In this work we propose a new indicator to classify the best period for longan fruit harvest, based on measurements of its longitudinal and transversal axis during growth. Shape analysis based on area per volume ratio (A/V) and sphericity show that those indicators stabilize after during longan growth period, independently of variety, in a specific environment. As sphericity increases 6% during fruits growth, A/V ratio decreases dramatically (75%) closing to maturity, at 120 days after anthesis. The first derivative of A/V ratio indicates three distinct phases that are related to the growth phases of fruits. We believe that those shape indicators could be used to probe the right point of longan fruits maturity in different environments in a quantitative way.

K e y w o r d s: tropical fruits, area per volume ratio, fruits maturity

INTRODUCTION

The international fruit consumption has increased since 1980´s, mainly due to the demands of natural products and the production diversification (Tibola and Fachinello, 2004). Despite most of the production amount is related to few fruits only, it has been noticed a significant increase in consumption of more exotic fruits like guava, mango, papaya and kiwi due to the changes of synthetic food antioxidants by natural ones (Moure *et al*., 2001). Brazil has great potential to produce exotic fruits due to its natural reserves, climate and soil with new land that is available for production, as has been shown for some fruits most recently (de Assis *et al*., 2008). Those conditions have favourable the species diversity cropped around the country and the interest of fruits production. Based on statistics of Brazilian agriculture department close to 30% of exotic fruit production in Brazil are from *Sapindaceae* family, like *Litchi Chinenses* Sonn. The longan fruit (*Dimocarpus longan* Lour.) that belongs to the same family that litchi is little explored in Brazil. Both are origin in China, but the longan tree is more rustic and adaptable to a larger climate amplitude that the litchi. The longan is native from 150-450 m height while litchi in original from sea level (Morton, 1987).

Mature longan fruits are usually small (1.5-2 cm diameter), conical, heart-shaped or spherical in shape and light brown in colour. It has a thin, leathery and indehiscent pericarp surrounding an edible white aril. The aril contains a relatively large dark brown seed. The longan growth development have a sigmoidal growth curve (Huang, 1995; Jesus *et al*., 2008) that can be divided in three main phases:

– intense cellular division by forming practically all the fruit cells,
– intense growth due to the aril increase,
– maturation and biochemical processes with accumulation of soluble solids, defining quality (Reuther, 1973).

Longan fruit are non-climacteric and will not continue to ripen in the post harvest, consequently, commercially is essential recognizing the harvest maturity. General guidelines for harvesting are difficult to prescribe because of the wide range of varieties grown. Maturity has been determined by fruit weight, skin colour, flesh sugar concentration, flesh acid concentration, sugar and acid ratio, flavour and/or days from anthesis (Wara-Aswapati *et al*., 1994). In practice, however, harvest maturity is usually qualitatively assessed on the basis of fruit colour and flavour (Jiang *et al*., 2002).

Quantitative analysis in this characterization have performed by using physical and/or geometrical aspects of tangerine fruit (Khanali *et al*., 2007), orange varieties (Topuz *et al*., 2004; Sharifi, *et al*., 2007), drying process of the coffee fruit (Corrêa *et al*., 2002) and wheat (Corrêa *et al*., 2006). Despite all the efforts, few works discuss the changes in shape and size, mathematically, considering surface area per

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volume ratio. The physical properties such as the respiration rate, gas permeability and weight can be related with the surface area and volume. Therefore, surface area and volume ratio (A/V) is an important aspect to be analyzed during fruits growth processes because A/V could be related to metabolic demands of heat production and transfer to air. Our hypothesis is that during growth fruits change its shape and sizes in order to get the right demands of heat and mass generation and transference of it to air.

The aim of this work is analysis the development of the six varieties of longan fruits during growth, in terms of its size and shape, by considering its A/V ratio and sphericity changes during growth period.

MATERIALS AND METHODS

This study was developed based on previous results (Jesus *et al*., 2008) conducted in the experimental farm of FCAV/UNESP ($21^{o}17'05''$ S and $48^{o}17'09''$ W), located 590 m a.s.l. in a tropical environment characterized as Cwa, according Köpeen by selecting six different seedlings of logan plant. In each plant were chosen 25 panicles whose fruits were not harvested during this study. Weekly evaluations were performed to measure the longitudinal (a) and transversal (c) axis of selected fruits after pulp formation (35 to 140 days after anthesis). All six varieties of longan fruits have been defined as oblate spheroids (a>c), based on their form. Thus, the volume (V) and surface area (A) can be calculated by:

$$V = \frac{4\pi a^2 c}{3}, \qquad (1)$$

$$A = \pi\left(2a^2 + \frac{c^2}{e}\log\left(\frac{1+e}{1-e}\right)\right), \qquad (2)$$

where: c and a are the transversal and longitudinal axis length of the longan fruit and e is the eccentricity: $e = \sqrt{1-\frac{c^2}{a^2}}$. The sphericity ($\varepsilon$) of the longan fruit is:

$$\varepsilon = \sqrt[3]{\frac{c^2}{a^2}}. \qquad (3)$$

Hence, longan fruit will be considered more to a spherical form when the sphericity is close the value 1 ($\varepsilon \approx 1$).

RESULTS AND DISCUSSIONS

Figure 1 presents the time changes of the sphericity (Eq. (3)) of the six longan fruits varieties studied from 35 to 140 days. It can be seen that in the beginning of the experiment (day 35) fruits were more in oblate format instead of spherical, and plants 1 and 2 presented a lesser spherical shape (ε = 0.83 and 0.86, respectively) than the ones presented in plants 3-6 (with values close to 0.90). Despite the changes in shape when the six different varieties and genotypes studied were compared in the start of growth process it is interesting to notice that those came together to a similar form, as sphericity converged close to 1, near day 120. This feature is also typically observed in litchi fruits but, contrarily, litchi develops a more elongated shape during growth (Salomão *et al*., 2006). Those differences observed when both species are compared can be due to the specific environmental conditions from where those came from. For longan the spherical form is more appropriated as those have smaller surface area when compared to elongated, conferring lesser heat changes with environment (Martins *et al*., 2003).

Figure 2 presents the A/V ratio (Eqs (1) and (2)) of longan fruits in all plants during the studied period. Once again differences in A/V ratio are present in the beginning of the growth period, as plant 4 presented smaller ratio values (close to 0.7 mm^{-1}) than plant 6 (with A/V = 1.150 mm^{-1}), for instance. During growth those differences are reduced as A/V ratios converge to a similar value (0.2 mm^{-1}) at the end of studied period (140 days). In fact, after 120 days of age we

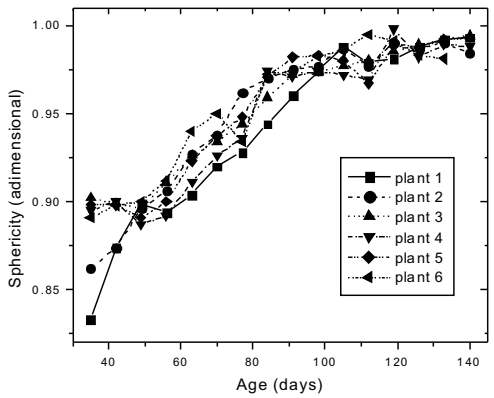

Fig. 1. Time changes of sphericity during the growth period for the 6 variety plants studied.

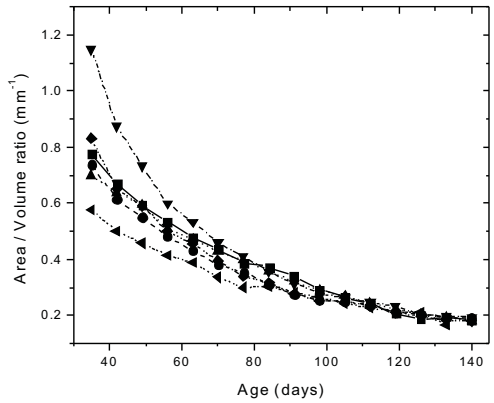

Fig. 2. Times changes of A/V ratio of the 6 plant varieties studied. Explanations as on Fig. 1.

had already observed the ripening of those fruits. On the other hand, Jiang *et al*. (2002) reported 75-78 days after anthesis as an optimal harvest period in China. Those environmental driven differences indicate the necessity of development of new indicators in order to determine the good harvest point of this fruit in different places around the world. We firmly believe that changes in A/V ratio would reflect the demands of longan fruits in heat and mass exchanges during the changes occurred from one phase to another. Our hypothesis is that heat and mass generation inside fruit are dramatically changed during growth period, while surface area has to adapt in order to have heat and mass production exchanged to air. This would be reflected in the A/V ratio as tool of the changes in growth period and the right point of harvest after its stabilization.

The knowledge of development phases during fruit growth is essential to guide the right cultural practices, especially close to maturation phase in order to handle fruit harvest (Grierson, 1995). Usually, that is not possible to distinguish, the limits between phases 1, 2 and 3 in growth period (Medina *et al*., 2005). Figure 3 presents the mean value of A/V ratio (squares, solid line, left axis) obtained from all varieties studied while in the same graph is presented its change in time, expressed by first derivative (triangle, dotted line, right axis). As already been observed in Fig. 2, in each variety individually, changes in A/V ratio are clearly observed during maturation of the fruit as A/V ratio decreases from 0.8 to 0.2 mm^{-1} in the 100 day period. The decrease of the A/V ratio seems to be related to the necessity of the fruit of keeping its internal mass and protect from heat and mass exchanges to atmosphere. These limits are clearly presented in Fig. 3, in the first derivative analysis where the changes in time of A/V ratio is presented (triangle, dotted line). At first up to day 50 of study, time changes in A/V were continuous, subsequently, close to day 60 up to 120 this ratio decreased quickly, while after day 120 we observe again a continuous rate of change in A/V ratio, close to zero. We believe that the stabilization of the time changes in A/V ratio could be used as tool for growth phase characterization and consequently the determination of harvest of longan fruits.

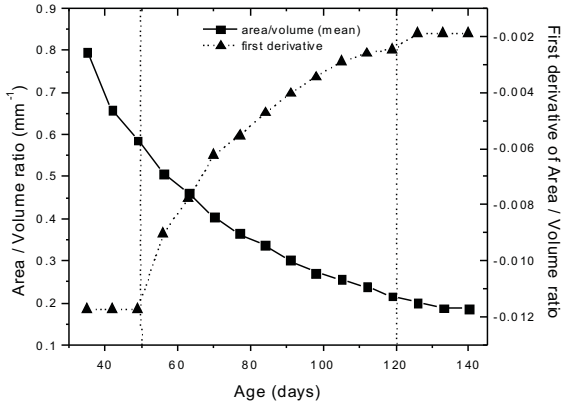

Fig. 3. Time changes of the mean A/V value (square, solid lines) and its first derivative in time (triangle, dotted line) during growth period.

CONCLUSIONS

1. Longan fruit sphericity and A/V ratio variety during growth up to reach maturity at 120 days after anthesis.

2. Stabilization of sphericity and A/V volume ratio was observed at 1 and 0.02 mm^{-1}, respectively, from 120 to 140 days after anthesis.

3. The time changes of A/V ratio have a sigmoidal form similar to the growth phases of longan fruits.

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