Juice sac granulation in'Itaborai' (*Citrus sinensis*) and its impact on fruit quality attributes

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ABSTRACT

Citrus fruits are subject to granulation disorder manifested by decreased juice yields and dry, hard unpalatable tissues. Harvesting time is one of the reasons causing onset of granulation.Although, farmers prefer on-tree storage of citrus for staggered and extended marketing periodbut fruits become prone to granulation. The fruit quality gets deteriorated resulting in consumer dissatisfaction and decline in commercial value. In this study, fruits of citrus genotype 'Itaborai' were stored on-tree 60 days more than the optimum harvesting stage.Physicochemical attributes were measured to determine the acceptable on-tree storage period. Granulation severity increased with delay of harvesting date. Specific density of fruits decreased by 16% and volume increased by 8%. The thickness of peel increased 1.1 fold. The TSS:acid ratio was 1.2 fold lowerin fruits harvested after a month.Hence, it is recommended that 'Itaborai' fruits be harvested not beyond30 days of on-tree storage.

Keywords: Citrus, Granulation,Itaborai, On-tree storage

I. INTRODUCTION

'Itaborai' is anearly season sweet orange cultivar relished for its juice content and flavour. Fruits have thin peel, are medium to large size and contribute essential nutrients, such as vitamin C and minerals [7]. However, lack of storage facilities is a major concern for the Indian citrus farmers. They usually practice on-tree storage of citrus fruit to prolong the market value without adding extra money for their storage [11].Reference [12] also reported on-tree storage to be better than off-tree storage as the fruits gets continued nourishmentfrom the tree. But one of the bottlenecks of on-tree storage is that it favours the incipience of granulation.Citrus granulation is a

physiological disorder mostly seen inthe advanced stage of fruit maturity. Several factors that favourthe augmentation of granulation include tree age, tree vigour, cultivar type, climatic conditions, soil edaphic factor, time of harvest etc. [9]. But till now the underlying mechanism remains unresolved. Granulation drastically reduces thefruit nutritional quality and its economic value. Moreover, citrus juice industry may face huge economic loss as juice yield reduces drastically with insipid taste. Researchers have performed several studies on varied aspects of different citrus genotypes however, the physicochemical characteristics of 'Itaborai'with respect to fruit maturity stage remains largely unknown.Further, since the disorder cannot be detected externally, the consumers can also get easily duped. Hence, we made an effort to correlate the commencement of granulation with loss in quality attributes with advancement infruit maturity.

II. MATERIALS AND METHODS

2.1. Procurement of fruits

Uniform sized fruits of citrus genotype 'Itaborai' were randomlyharvested from a healthy tree budded on *JattiKatti*(*Citrusjambhiri*) rootstock. Four stages for harvest were selected: Optimum maturity stage when fruits attained TSS:acid ratio ≥12 (stage 1); 20 days extra on-tree storage (stage II); 40 days over the optimum harvesting stage (stage III); 60 days over the optimum harvesting date (stage IV). Fruits harvested on each stage were subjected to quality evaluation.

2.2. Physicochemical analysis

The average volume (cm^3) of fruits was determined by water displacement method. Specific gravity was calculated by dividing the fruit weight by its volume and was expressed in terms of g/cm^3.The peel thickness was measured with the help ofverniercaliper and expressed in millimeters (mm) [1]. Granulation severity was measured by the method of [8]. Ascorbic acid was determined by titration method using dye 2,6dicholorophenol indophenol as described by[6]. Total sugars in fruit juice were estimated using the method described by [5].

2.3. Statistical analysis

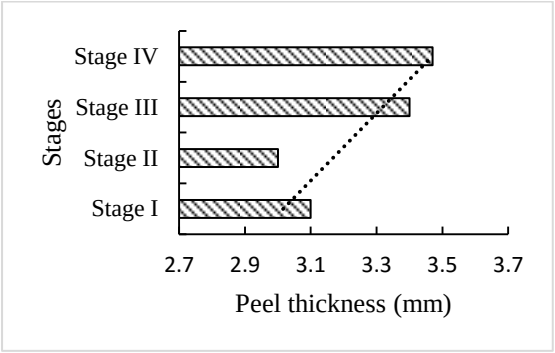
The experiment was carried out during 2017-2019. Pooled data obtained from the experiments were analyzed using OP Stat with 3 replicationsand the results were compared from ANOVA by calculating the LSD at 0.05 [4].

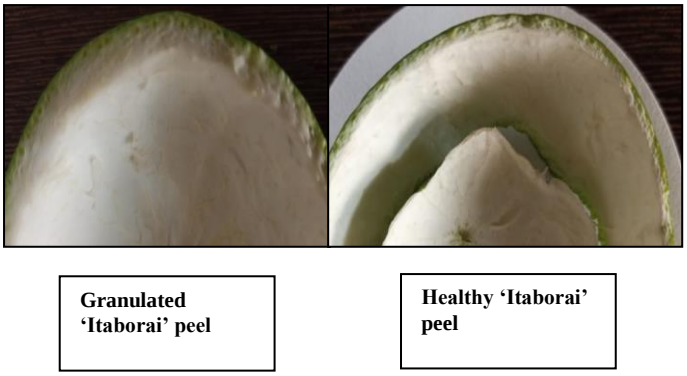
 ISSN: 2229 - 6646

III. RESULTS AND DISCUSSION

3.1. Peel thickness

As shown in Fig 1, peel thickness varied from 3.1 mm to 3. 47 mm for fruits harvested on the four different stages. Peel thickness of fruits increased eventually with the progress of on-tree storage or harvesting time. For fruits harvested at stage IV i.e., 60 days above the optimum fruit maturity, peel thickness increased 1.1 fold compared to stage I. The increase in peel thickness might be due to reallocation of nutrients from pulp to peel in the advanced stage of fruit maturity and the increased percentage granulation [3].





Granulated 'Itaborai' peel

Healthy 'Itaborai' peel

Fig. 1 Peel thickness (mm) of 'Itaborai' fruit with respect to their stages

3.2. Specific gravity

Fig 2 depicts the changes in specific gravity of fruits with respect to advancement in on-tree storage of 'Itaborai' fruits. The specific gravity varied from 0.83 to 0.72 g/cm^{3}for the fruits with non-significant variation during the first two stages of harvest. Fruits harvested at stage III exhibited an increase in the specific gravity owing to the gelatinous phenomenon wherein again decline in specific gravity of fruits at stage IV might be due to substrate utilization for secondary cell wall synthesis in granulated juice vesicles [1]. Thefruit volume also increased up to 8.3% in stage IVnot due to the cell multiplication [7] but because of the hypertrophy phenomena (content volume increases).

 ISSN: 2229 - 6646

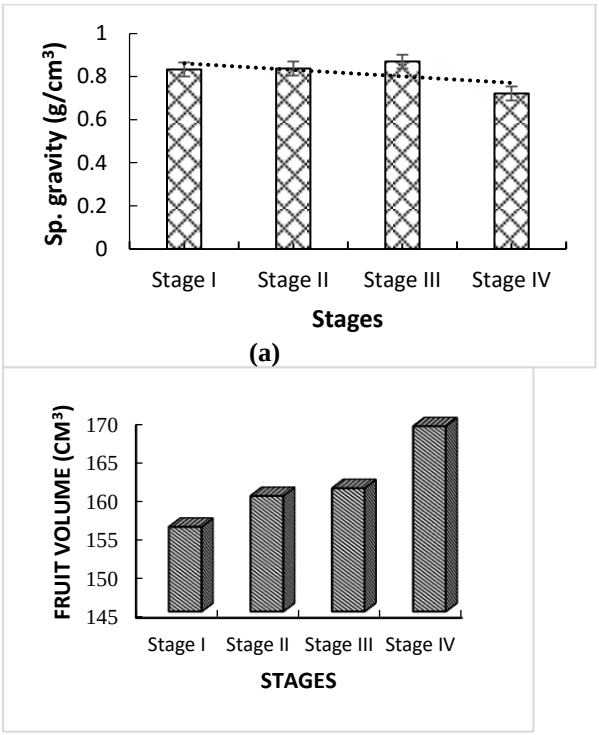


Fig. 2 Changes in (a)specific gravity and (b) fruit volume of 'Itaborai' fruits harvested at different stages

3.3. TSS:acid ratio and total sugars

As evident from data given in Fig 3, both TSS:acid ratio and total sugars in fruits declined with advancement in on-tree storage. At optimum maturity the TSS:acid ratio of fruits was 14.23 which drastically reduced to 11.42 at stage IV (60 days of on-tree storage). The total soluble solidsdecreased up to 1.2 fold resulting in flat insipid taste of the fruits that reduces the preference by customers. The total sugarsmainly comprises of sucrose that is used as fuel during respiration.The substantial decline of both the parameters might be due to the substrate utilization during high respiration, energy used for secondary cell wall synthesis [2].

 ISSN: 2229 - 6646

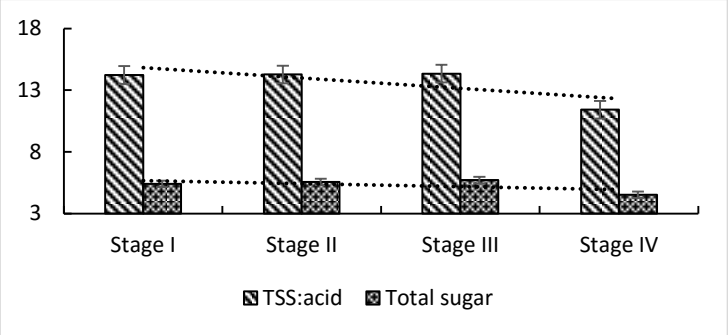


Fig. 3TSS:acid ratio and total sugars (%) of 'Itaborai' fruits with respect to their harvesting stages

3. 4. Correlation between granulation severity and vitamin C content

Severity of granulation eventually increases with the progress of time as it is a senescence related process. Although, in stage I (i.e. optimum fruit maturity) the granulation percentage was 0, but till the fruit reaches stage IV i.e., after 60 days of on-tree storage,the granulation percentage reached 60% which is highly unacceptable. The same is well correlated with vitamin C content. The vitamin C content decreased drastically with an increase in granulation severity (Fig. 4). Our findings arecorroborated with the earlier findings of [8].

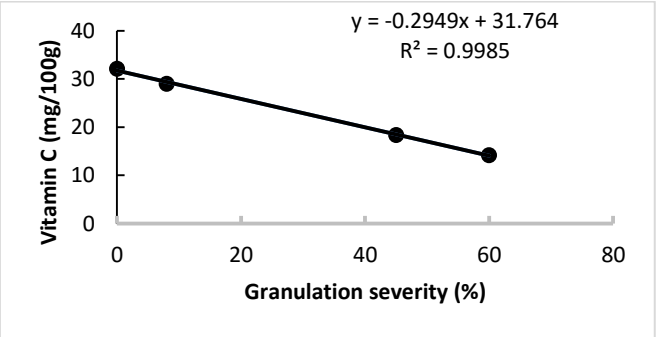


Fig. 4 Correlation between vitamin C and granulation severity of 'Itaborai' fruits

3.5. Opacity of juice sac and seed health

Granulation disorder is manifested by changes in the juice vesicle tissues and the seed size. As depicted in Fig. 5 (a), the juice vesiclesaretransparent and filled with abundant amount of juice whilst the granulated juice sacs(Fig. 5b) are opaque

ISSN: 2229 - 6646

discoloured and dried. As evident from Fig. 5b,seeds in healthy citrus fruit are sound and bold (stageI) compared to the seeds in granulated fruits (Fig 5b). The decrement in quality may be imposed by granulation wherein the juice content is drastically reduced due to gelatinization and lignification also affecting the seed health and vigour [10].

Fig. 5(a) Healthy juice sac & seeds; (b) Granulated juice sac & seeds of 'Itaborai' fruits

IV. CONCLUSIONS

Advanced stage of fruit maturity is one of the reasons of granulation commencement.Granulation not only affects the anatomical structure of juice sac but alsodiminishes the physicochemical attributes. The juice sac is dried up severely, hence no extractable juice owing to customer dissatisfaction and diminishes the commercial value of citrus. Granulation severity increases eventually with respect to harvesting time. The fruits of 'Itaborai' should not be left on tree for more than 30 days as beyond that granulation severity increases whichis highly unacceptable to the consumer and also the juice processing industries as juice yield is drastically reduced. The malady can't be detected externally until and unless the fruit is cut open. The simultaneous decrease in specific gravity with advancement in granulation severity may be a helpful tool for consumers to segregate the healthy fruits from granulated ones.

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