

Determination of optimum maturity of north Sri Lankan Kilichondan Mango fruits (*Mangifera indica* L.) based on their biochemical properties

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ABSTRACT

Mangoes (*Mangifera indica*, L.) produced in Northern Sri Lanka, are lost due to poor transportation and storage facilities. Optimum date for harvesting was determined to extend the postharvest life. Harvest maturity of Kilichondan mango cultivars grown in Northern Sri Lanka between April and January, were studied to reduce such losses. Though Kilichondan mangoes are delicious and economically positive for the poor, the maturity index of this variety has not been determined yet. Therefore this study was aimed at recommending proper maturity indices for Kilichondan mango and to analyze the physical and chemical properties of this fruit during ripening. Time after the full bloom stage, the colour of the skin, floating / sinking ability, total soluble solids (TSS), titratable acidity (TTA), moisture content, dry matter, TSS/TTA ratio were measured. Most fruits sank in water. TSS, pH, dry matter content increased rapidly, whereas TTA and moisture content percentage decreased rapidly towards maturity. Fruits harvested up to 93 days from full bloom stage, showed significant differences in the above mentioned values than the fruits harvested after 93 days from full bloom stage. 90 percent of fruits ripened on the tree after 97 and 98 days from full bloom stage where as fruits harvested after 98 days from full bloom stage were over-ripened and of poor quality. Since a non-destructive method reduces loss of yield, the study recommends the slightly yellow colour patch on the green shoulder, is an acceptable maturity index that appears on the 93rd day from full bloom stage for Kilichondan mango variety. Testing panel results confirmed the acceptable eating quality of these fruits after being ripened.

Keywords: Kilichondan mango; *Mangifera indica*; Maturity index; full bloom stage

INTRODUCTION

Mango trees (*Mangifera indica*, L.) are widely grown for their delicious fruits and economically important tree parts, in tropical and subtropical regions of the world. The mango fruit is considered as the King of all fruits because of its taste and odour. The fruits are used in various forms such as pickles, curries, preserves, cordials, juices and chutneys of many sorts. The fruit is rich in antioxidants and it is useful for treating cardiac diseases in Siddha medicine. Anti cancer and antiviral activities were also reported for the fruit [7]. Chemical composition of mango fruits differs with regard to different cultivars and area of production [1, 15]. In Sri Lanka, the success of mango cultivation could be attributed to the diverse environmental conditions across the country, which extends the fruiting season to eleven months a year [20]. Some mangoes bear fruits twice a year [25]. Due to poor transportation and storage facilities, mangoes produced in remote areas of Sri Lanka are sold at very low prices compared to prices offered in the cities. To help rectify this situation, the possibility of harvesting mango fruits at optimum maturity to extend the shelf-life of the fresh produce was explored. The quality as well as the postharvest life of the fruit is influenced by the time

and stage of maturity at harvest [6,17]. However, proper quality, taste and flavor of mangofruit can only be guaranteed when fruits are harvested once they attained the physiological maturity [31,34]. The physiology and biochemistry of over mature / over ripen fruits differ from that of exactly mature ones in terms of rate of respiration, rate of transpiration, converting ability of starch to sugars susceptible to pathogen attack and storage life [15,18].

Maturity standards based on physic-chemical parameters must be tested to assure that only high quality fruits are harvested [28,9,22] Physical indices of maturity such as weight, size, shape, external skin colour, number of days from bloom to harvest, specific gravity and fruit pressure are widely used as criteria for harvesting diverse fruits [23,16,8]. Maturity of mango could be predicted by measuring size, color and firmness [16]. Chemical parameters used in determining the maturity are TSS, total acidity and pH, acid/sugar ratio, reducing sugars, tannins, volatile substances, ascorbic acid and oil content [1, 9, 15,18].

The number of days from flowering and fruit set to harvest could be a good nondestructive maturity index for diverse fruit varieties [8,14,22,28,34]. Lateharvested fruits resulted in sweeter fruits and had a different volatile profile from earlier-harvested fruits [22]. Mangoes collected 100 days after flowering developed better organoleptic characteristics than those harvested earlier[8]. This will improve the fruit quality through reduction in *Colletotrichum* and *Dothoriella* sp diseases [14]. Specific gravity is also a nondestructive easily measurable maturity index[28]. However, fruit size will decrease due to shrinkage of fruit during growth and storage [16]. Skin colour has been used as a standard maturity index for harvesting of mangoes [1, 6,15, 16, 23].Maximum red coloration is more sensitive maturity index than the maximum yellow coloration[23]. Sometimes plant biologists determine the appearance of red color on the skin is not a reliable index of maturity. Likewise, the change in skin colour from dark-green to light-green or yellow is not reliable because of variations between cultivars and growing conditions. Skin color measured by colorimeters and spectrophotometers are used to predict maturity index and ripeness in mangoes [16,17,22]. A non-destructive method for predicting maturity using colour values taken by a handheld Hunter Lab colorimeter has been in practice [17]. Mature fruits could ripe with highly preferred taste while fruits predicted to be immature or over ripened were mostly rejected by the testing panels [17]. Using the electronic nose or gas chromatography for aroma and other volatiles as well as for soluble solids and acids, markers are determined[22].

Harvesting mangoes in a single picking is the common practice in Sri Lanka and this may result in removal of more immature fruits than mature fruits. Immature mangoes do not ripen naturally when letting to ripe out of the tree. Artificial stimulated ripening such as fuming or usage of chemicals could end up with low quality fruit with poor taste and odour. Therefore, harvesting at the exactly optimum stage of maturity using the appropriate maturity index or indices is extremely important[20]. In different countries numerous researches are going on to determine the optimum stage of maturity for harvesting of mango fruit[26]. The criteria used were based on the physico-chemical factors and the respiratory physiology of the tree and the fruit. The Kilichondan type mango tree is moderately vigorous in fruit production, attaining a spread of 5 -7 meters and height of 7 – 9 meters at the age of 10 years. This variety is one of the high yielding one and starts bearing fruit after 5 years of planting in Sri Lanka [25]. The fruits are generally green and become yellow after ripening. As more fruits mature and ripen on the tree, the damage by birds and animals also increases. In the meantime, if they are harvested early then they will not research acceptable eating quality, after ripening. The maturity index of Kilichondan variety that is one of the north Sri Lankan special has not been determined yet. Therefore this study was aimed to access the optimum maturity indices for harvesting Kilichondan mango fruits in Northern Sri Lanka to withstand handling, transportation, storage and to extend the postharvest life.

MATERIALS AND METHODS

Plant Material

Six to twelve years old Kilichondan mango trees (*Mangifera indica*, L.) were randomly selected in the Thirunelvely area of the Northern Sri Lanka. Mango trees of each cultivar were uniform in appearance and vigor. All trees received the same cultural practices and a single application of farm manure applied annually following harvest and prior to the beginning of the rainy season.

Harvesting and maintaining

Around 500 panicles of inflorescences were marked at the full bloom stage and carefully observed from the day of marking. Tagging of inflorescences in each tree was made using a label showing dates of flowering. Ninety days

after full bloom stage, 48 fruits were randomly harvested by handpicking from all over the tree by a cloth bag attached to a long pole and brought to the laboratory. Care was taken to obtain fruits of similar size and skin color as an indication for visual analysis. All the fruits were washed with distilled water and air dried. One lot was analyzed as fresh fruits for weight, specific gravity and chemical characters to determine total soluble solids (TSS), pH, titratable acidity (TTA) and TSS/TTA ratio. The other lot was analyzed, after ripening under laboratory conditions, to determine physical and chemical characteristics, the number of days required for ripening of the fruits and taste. Fruits of the second lot were kept in baskets made from sugar cane sticks. Baskets were lined with dried rice grass (hey) and the fruits were also covered with the dried rice grass. Ripening took place at room temperature of 32-35°C. Fruits were inspected daily for visual change in color (from green to yellow/any other) and pressed manually for flesh firmness.

Analytical Methods

Fruit fresh weight (g) was measured using a top loading sensitive balance. Specific gravity was measured by weighing the fruits first in air and again in water and by observing the fruit whether it sinks or floats in the water. The period required for ripening of fruits kept in baskets was calculated by taking the average period required for all the fruits (10 pieces) to reach ripening. Five grams of mango pulp was weighed in weighing balance and then kept in oven for 48 hours at 60°C. Dry weight was later measured. Dry matter and moisture content (%) were measured using the following formula.

$$\text{Dry matter} = \frac{\text{Weight after drying} \times 100}{5}$$

$$\text{Moisture content (\%)} = \frac{(\text{Fresh weight} - \text{Dry weight})}{\text{Fresh weight}} \times 100$$

The pulp was crushed using a blender and then filtered through a muslin cloth. Filtered juice was used to measure the following parameters. Titratable acidity measured as % citric acid of fresh mango juice was determined by titrating the sample to pH 8.2 with 0.1 N sodium hydroxide (NaOH) [29]. The pH of mango juice was measured by the Griffin pH meter. Total Soluble Solids (TSS - Brix) of fresh mango juice was measured by a Kruss hand refractometer model HRN-32. Data obtained were correlated with harvesting date, which was taken as the independent variable. After the fruits reach the acceptable eating quality, each set of ripened fruits were subjected to the tasting panel, contained 25 people. The terms used to measure the taste were excellent, very good, good, poor and bad.

Experimental Design

Sampling of fruits was made in a completely randomized design. Data obtained from measuring physical and chemical characteristics were correlated with harvesting date, which was taken as the independent variable. The data were subjected to variance analysis using the SAS package. Least square means procedure was used to separate treatment means when differences were significant ($P < 0.05$) [35].

RESULTS AND DISCUSSION

During the ripening of Kilichondan, pH, dry matter and brix increased towards maturity where as the titratable acidity, moisture content and weight of the whole fruit decreased.

Fruit colour

The fruit colour remained green until ninety first day of development from full bloom stage and at ninety second day of development, slight yellow colour patch started to develop at the shoulder. The yellow colour started to spread towards the middle part of the fruit at ninety fourth day from full bloom stage. On the 97th and 98th days from full bloom stage, the colour spread to half to three fourth of the total skin. The fruits became fully yellow on the 99th day, orange on the 100th day and started to shrink later. Fruits looked like oval until the 9th week from full bloom stage and then started to develop cheek and the shape changed to cylindrical. Decrease of size and sphericity of harvested mango are mainly due to shrinkage [16]. The weights of both hard and ripe fruits did not show specific trend of change and no significant correlation between fruit weight and harvesting date was recorded.

Specific gravity / Sinking and floating

Most of the fruits harvested after 90 to 93 days from full bloom stage floated in water whereas the fruits harvested after 93 days sank in water with a few floating. Specific gravity of both hard and ripe fruits of the Kilichondan showed fluctuating patterns of increase and decrease with regard to harvest time, without any significant correlations. Generally mangoes with specific gravity higher than 1.0 will sink in water due to higher dry matter content of the fruit [21]. A specific gravity of about 1.02 could be considered as a good maturity index for mangoes [28].

pH

There was an increase in pH of the fruit pulp, total soluble solid content and dry matter up to 95th day of maturity while titratable acidity and moisture content showed a decreasing trend, up to that level. There was no significant difference among the fruits harvested after 95, 96, 97, 98, 99 and 100 days from full bloom stage in the pH value (Figure 1). The pH has been correlated to maturity index in mango [8,12,15,22,33] and strawberry [11]. Using NIR spectrometry, acidity was accessed nondestructively and used as a maturity factor of mango fruit [33]. Titratable acidity correlated positively with maturity of a mango variety [8]. Citric acid was used to maintain apple slices at acidic condition for 10 days [12].

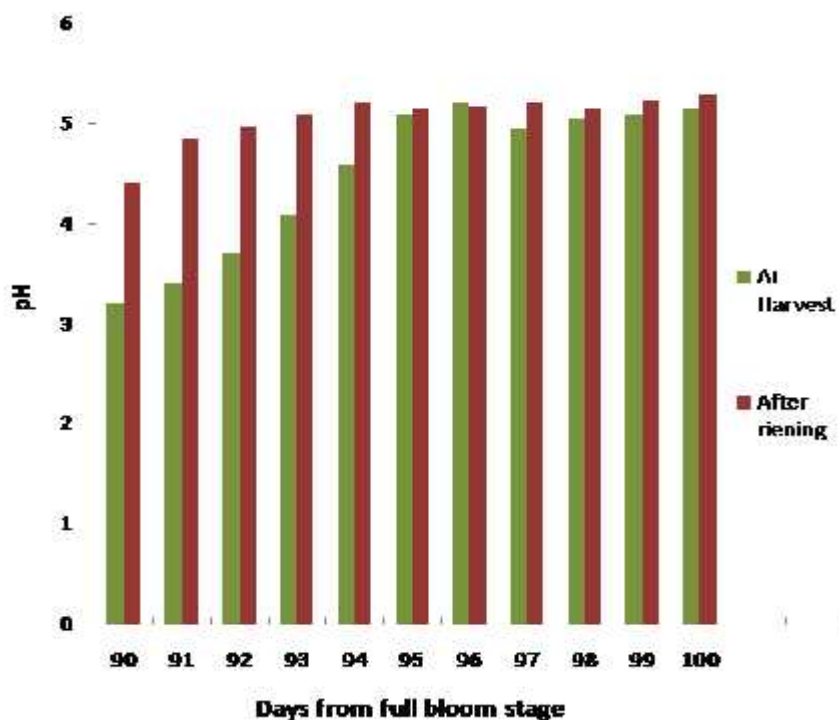


Figure 1: pH of the Kilichondan mangoes (*Mangifera indica*, L), harvested after 90 to 100 days from full bloom stage

TTA, TSS, TSS:TTA, Moisture content & dry matter

There was an increase in TSS of the fruit pulp, total soluble solid content and dry matter up to 94th day of maturity while titratable acidity and moisture content showed a decreasing trend, up to that level (Figures 2, 3, 5 and 6). There was no significant difference among the fruits harvested after 95, 96, 97, 98, 99 and 100 days from full bloom stage in TSS and dry matter (DM).

During the process of fruit maturation, TSS:TTA ratio increased and this revealed the sweetness of the fruit increases towards maturity (Figure 4). This ratio had a significant increase up to 93rd day of maturity from full bloom stage. However there was no significant increase in fruits harvested after 95th day of maturity. Changes in the chemical composition after ripening are presented in the tables and the respective figures. TSS of the ripened fruits increased significantly as maturity advanced every day while TTA and moisture content showed significantly decreasing trend. The fruits harvested after 97 days from full bloom stage showed a very high TSS:TTA ratio and moisture content. These fruits were of poor quality due to the lower tasting grade, higher susceptibility of spoilage

and off flavour. Dry matter contents of the ripened fruits were significantly higher than the non-ripened fruits. Loss of water during ripening by transpiration through stomata and pores of the skin and the sap that transports the chemicals and sugary contents towards the ripening fruit may be a reason for the raise in the dry matter content.

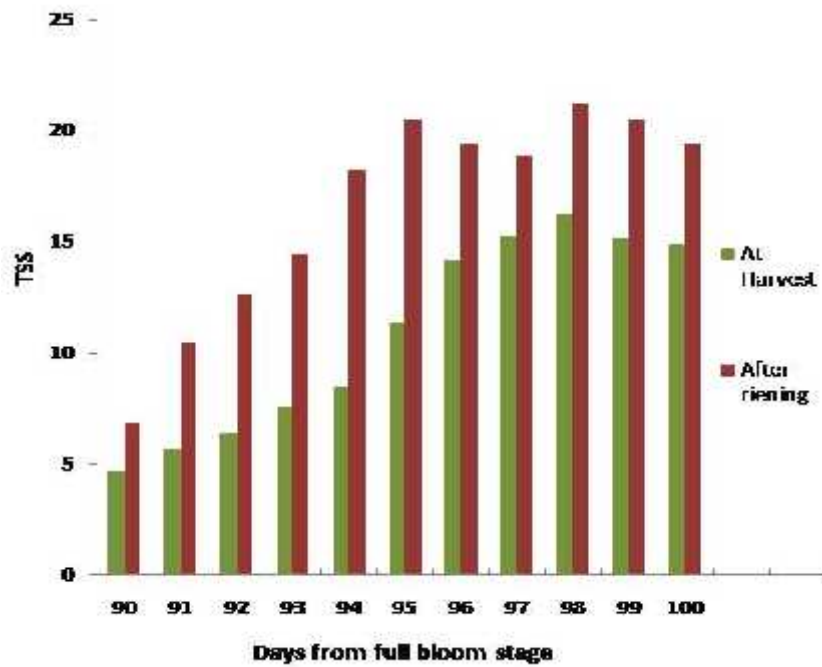


Figure 2: Total soluble solids (Brix %) of the Kilichondan mangoes (*Mangifera indica*, L), harvested after 90 to 100 days from full bloom stage

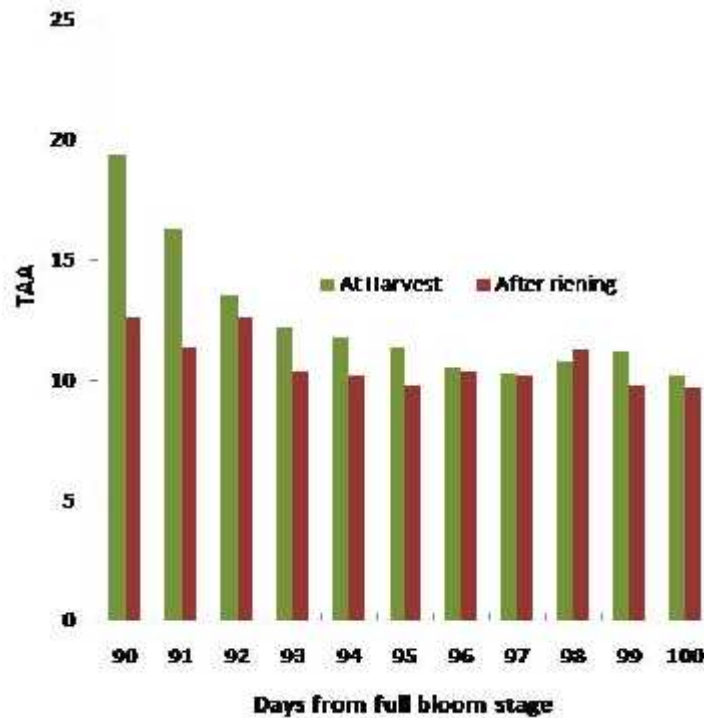


Figure 3: Titratable acidity of the Kilichondan mangoes (*Mangifera indica*, L), harvested after 90 to 100 days from full bloom stage

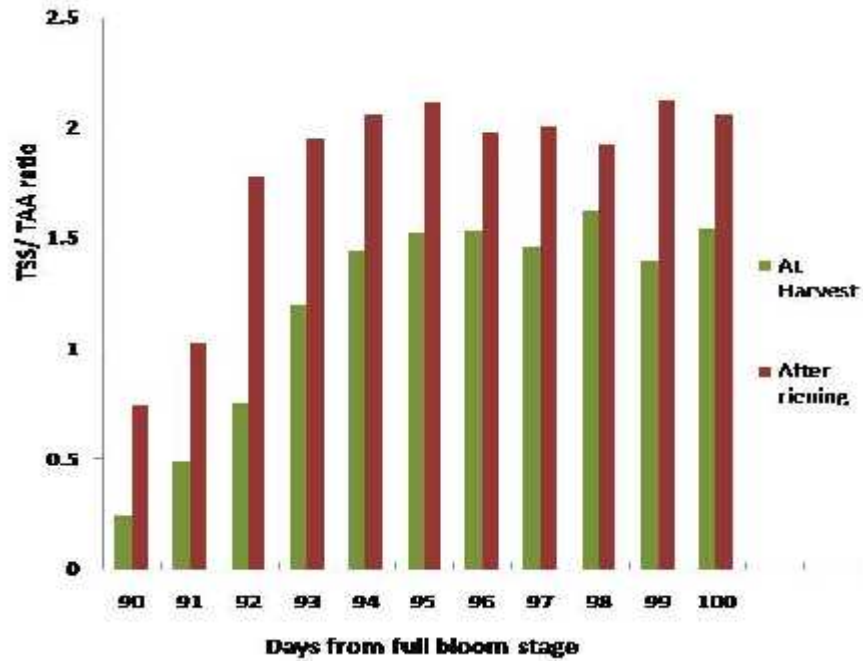


Figure 4:Ratio of TSS / TAAof the Kilichondan mangoes (*Mangifera indica*, L), harvested after 90 to 100 days from full bloom stage

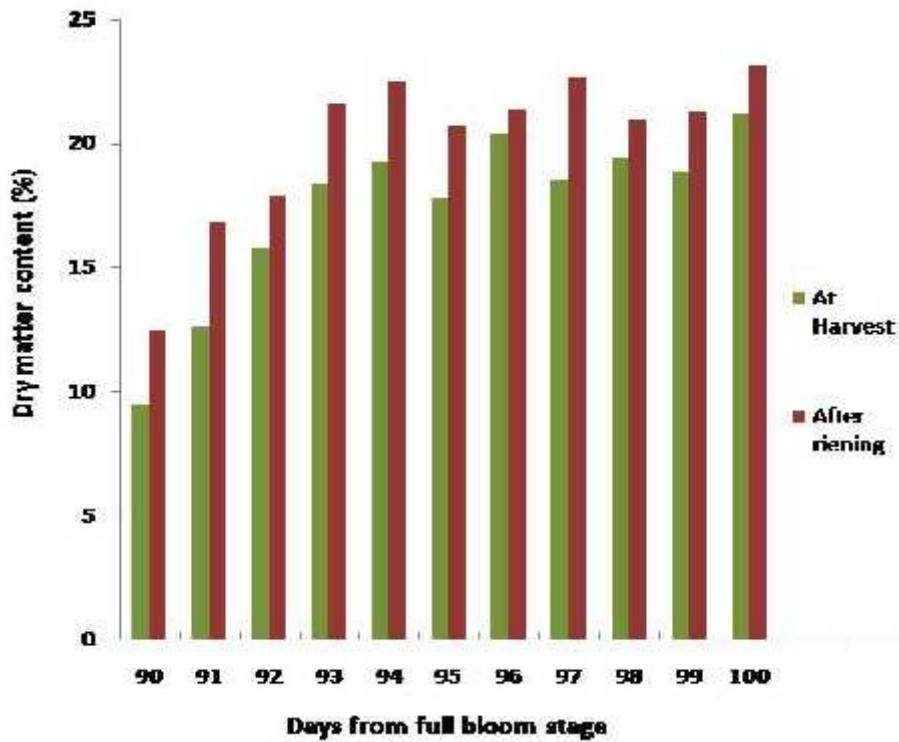


Figure 5:Dry matter content of the Kilichondan mangoes (*Mangifera indica*, L), harvested after 90 to 100 days from full bloom stage

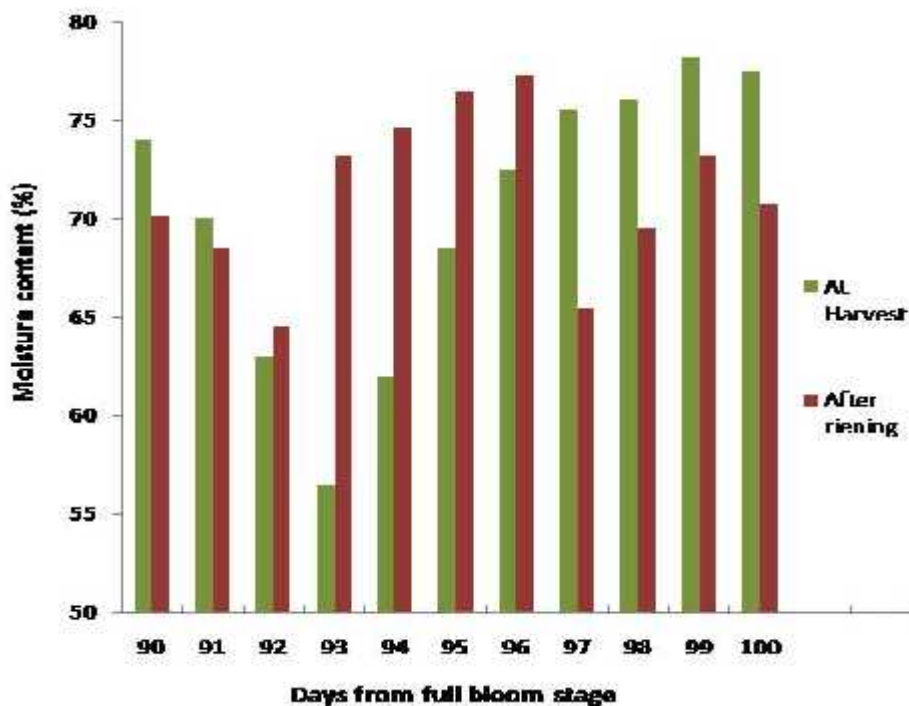


Figure 6: Moisture content (%) of the Kilichondan mangoes (*Mangifera indica*, L), harvested after 90 to 100 days from full bloom stage

Taste of the fruit

The fruits harvested after 93 days from full bloom stage were much sweeter than those harvested before 93 days from full bloom stage (Tasting panel results are shown in the table 1). This may be due to the higher TSS: TTA ratio, lower moisture content and aroma generation in the older fruits. Even though the fruits harvested after 96, 97, 98 and 99 days from full bloom stage are of pretty reasonably accepted eating quality, they cannot be left on the tree until development because they are susceptible for bird and animal peck. Mangos collected at 100 days after flowering developed better sugar content and other organoleptic characteristics than earlier harvested fruits[8]. Using the enose and GC for soluble solids, delay in harvesting resulted in sweeter fruits[22].

Spoilage percentage

The fruits harvested after 90, 91 and 92 days from full bloom stage showed higher percentage of spoilage than the fruits harvested after 93 days from full bloom stage. This may be due to the moderate moisture content and higher acidity of the immature fruits. Coatings delayed mango fruit ripening and improved keeping quality and extended storage life with appreciable retention of all quality parameters [6,1].

Table 1: The tasting panel results of Kilichondan mangoes after ripening

Days from full bloom	Fruit taste quality (100%)				
	Excellent	very good	Good	Poor	Bad
90	-	6	36	31	27
91	-	3	28	37	32
92	4	8	24	48	16
93	9	26	16	39	10
94	5	16	32	33	14
95	9	28	16	25	22
96	8	28	18	42	3
97	12	24	32	32	0
98	8	24	24	24	24
99	2	28	20	44	6
100	0	2	25	54	19

Maturity index for harvesting

Harvesting of Kilichondan mangoes after 90, 91 and 92 days from full bloom stage (Figure 7 shows the full bloom stage) are not recommended because the taste of the fruits are not acceptable. Harvesting at very late stage of

development (97, 98, 99 and 100 days after full bloom stage) will lead to higher chances of spoilage and the fruits might be pecked by birds and animals when they are on the tree. The degree of shrinkage in Kilichondan decreased as picking time advanced. The occurrence of shrinkage is natural in the 90-93 days of fruit growth, due to moisture loss [9]. Therefore 93rd day from full bloom stage would be an ideal choice for harvesting Kilichondan mangoes. At this stage slightly yellow patch on the green shoulder is the skin colour and this is clearly visible, appropriate, non-destructive maturity index. The values of pH, TSS, DM, TTA and moisture content of the fruit at this stage of maturity, were 5.35, 13.18, 16%, 13.50 and 76% respectively and these values could be used as maturity indices of Kilichondan mango variety. These results will aid in harvesting mango fruits at optimum maturity to extend the shelf-life and overcome poor transportation and lack of storage facilities in the tropical regions.



Figure 7: Full bloom stage of Kilichondan mango

CONCLUSION

The Kilichondan mangoes growing in the tropical region like Northern Sri Lanka could be harvested 93 days after the full bloom stage. These fruits had acceptable visible and sensory qualities after ripening. At this stage of maturity, the fruits developed yellow colour patch at the shoulder. Developing fruits that contain pH 5.35, TSS 13.18, dry matter 16%, moisture content 76%, TTA 13.50 could be considered as matured and would be ready for harvesting.

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