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DETERMINATION OF MATURITY INDICES IN MANDARIN ORANGE

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Abstract

The experiment was conducted at the Regional Horticulture Research Station (RHRS), Akbarpur, Moulvibazar during 2010 to standardize the optimum harvesting time of three genotypes of mandarin based on better physical, chemical and qualitative characteristics of fruits. The mandarin genotypes namely CR-Mou 007, CR-Mou 008 and BARI Komala-1 were used in the experiment and the fruits were harvested at 15 days interval starting from 1st October 2010. The initial sign of mandarin maturity was a change in peel colour, from green to orange. The fruit colour of CR-Mou 007 (Nagpuri), CR-Mou 008 (Khasi) and BARI Komala-1(Khasi) changed gradually from deep green (01 October) to orange colour (01 December) with the delay of harvesting. The heaviest fruit (142.50 g) was found in BARI Komala-1 harvested at 01 December, which was statistically identical with the fruit of CR-Mou 008 harvested from 16 November to 01 December. Maximum juice content (52.07 %), total sugar (7.47 %), reducing sugar (3.15%) and sugar acid ratio (11.20) was observed in BARI Komala-1 when harvested at 01 December. The mandarin was sour at early harvesting at 01 October and turned to sweet in 01 November and very sweet in 16 November and 01 December. The highest sugar acid ratio (11.20) was recorded in BARI Komala-1 when harvested at 01 December. The mandarin fruits possessed better quality in respect of physicochemical and qualitative characteristics if harvest during November to 1st week of December when fruit age ranged from 245 to 260 days from fruit set.

Keywords: Determination, maturity indices, mandarin orange.

Introduction

Mandarin **(***Citrus reticulata* Blanco) is considered as one of the most important and popular citrus fruit in the world and in Bangladesh as well. It is cultivated widely in the tropical and subtropical regions. The fruits are usually harvested when they attained the harvestable maturity stage. There are several computational and physical methods to determine the maturity stage. It is normally specific to a variety that takes a fixed period to harvesting from full bloom. Accordingly, it is possible to ascertain calendar dates for plucking fruits in an orchard. Colour change of fruits is also an indicator for maturity in some varieties such as Kinnow mandarin. But environmental conditions particularly temperature, relative humidity and sunshine may alter the period of ripening (Mukhopadhayay, 2004). In view of the market demand, delayed maturity often becomes necessary. The last and most important aspect of fruit development is the

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maturity stage and it is biologically most active phase, often involving high metabolic activity and cellular changes which leads to change in colour, aroma, flavour and texture of fruits. Appropriate harvestable maturity of fruit prolongs the storage life and postharvest-storage quality (Reid, 1992; Deka *et al.*, 2006). Biochemical changes during growth and development of fruits is an important factor in fixing the appropriate maturity indices of the fruit. Standardization of maturity indices of mandarin is very much required to reduce the post-harvest losses during post-harvest handling and transportation and also pave the way of fruit quality maintenance (Deka *et al.*, 2006). Van Rensburg *et al.* (2004) reported that 'Nules Clementine' mandarin fruit harvested late in the harvest period are more susceptible to rind cracking than fruit harvested earlier. In Bangladesh, farmers often harvest fruit at immature stage because of premature fruit drop (August to October) which reduces the fruit quality and shorter the shelf-life. The market of mandarin in the country usually starts at early November which is abundant with imported fruits and the farmers of Bangladesh has little scope to compete with and thus culminate them premature harvest for capturing early market even before the imported fruits flourish, The mandarin growers in the country are not aware of maturity indices of the fruit which is yet to be standardized. Therefore, the present study was carried out to know the physico-chemical changes in mandarin fruit during maturity and thereby standardize the optimum harvesting time of different mandarin genotype in the study area.

Materials and Methods

An investigation was carried out at the Regional Horticulture Research Station (RHRS), Akbarpur, Moulvibazar of Bangladesh Agricultural Research Institute (BARI) from March 2010 to December 2010. The orchard is located at $24^0$24'-$24^0$38' North latitude and $91^0$37'-$91^0$50' East longitude in the Agro-ecological Zone (AEZ)-20 that represent the Eastern Surma-Kushiyara Floodplain and about 200 km North-East to Dhaka. The selected site for mandarin maturity indices was situated in the subtropical climatic zone characterized by heavy rainfall during May to September and the rainfall was scanty during the rest of the months of the year. The experiment was laid out in factorial Randomized Complete Block Design (RCBD) with three mandarin genotype and five harvesting dates having three replications. The mandarin genotype CR-Mou 007 (Nagpuri type), CR-Mou 008 (Khasi type) and BARI Komala-1 (Khasi type) were selected for this study. The age of the trees varied from ten to twelve years. The orchard was maintained with appropriate production practices. Fruits were collected randomly five times at 15 days interval during 01 October to 01 December 2010 and the age of fruits was recorded from the fruit set. A total of ten fruits were taken from each replication.

Data were recorded on physical parameter of mandarin fruits viz. fruit weight, fruit length, fruit diameter, juice content and total soluble solids. Chemical parameters of fruits such as total sugar, reducing sugar, titratable acid and ascorbic acid (Vitamin C) content of fruit were estimated and accordingly sugar acid ratio was calculated. Chemical parameters

were determined by the methods described in the Manual of Analysis of Fruit and Vegetable Products (Rangana, 1986). Besides, data on qualitative characters namely fruit colour, juice sac colour, peeling quality, sweetness and taste were also recorded. The juice was tasted organoleptically by a panel of ten members for sweetness and taste.

The recorded data for different characters were analyzed statistically using MSTAT-C program. Means were compared by Duncan Multiple Range Test (DMRT) and Coefficient of Variation (CV) was also estimated (Gomez and Gomez, 1984).

Results and Discussion

Physical properties of mandarin fruits with reference to genotypes: Mandarin genotype varied significantly with respect to physical properties of fruits such as individual fruit weight, fruit diameter, fruit length and total soluble solids content (Table 1). BARI Komala-1 produced comparatively heavy fruit (132.1 g) with larger diameter (6.11 cm) while CR-Mou 007 produced lighter fruit (103.8 g) with smaller diameter (5.08 cm). The fruit length (5.59 cm) was higher in CR-Mou 008 which was statistically at par with BARI Komala-1. Altaf *et al.* (2008) obtained 101 to 287 g fruit weight in Kinnow mandarin. They also reported fruit length of mandarin varied from 4.2 to 7.0 cm and fruit diameter 5.2 to 8.5 cm. The juice content of tested mandarin fruits varied from 45.20 to 47.15% among the genotypes/variety. The higher percent of TSS (8.2%) were recorded from both BARI Komala-1 and CR-Mou 008 and lower (7.7%) from CR-Mou 007 (Table 1). Altaf *et al.* (2008) obtained 8-12.5% TSS in mandarin fruits.

Physical properties of mandarin fruits with reference to harvesting dates

Harvesting time had significant effect on individual fruit weight, fruit diameter, juice content and TSS content of mandarin fruits (Table 2). The lowest fruit weight (103.0 g) was recorded from 01 October harvest and the highest (128.2 g) from 16 November (245 days after fruit set) and fruit weight was declined afterward. The diameter of fruit was increased significantly with delayed harvesting, though it was not statistically different when harvested during 16 October to 01 December. Dris and Jain (2004) reported fruit weight, length and diameter rapidly increased from 26 August to 24 November, and then slowly increased as the fruit reached maturity. Juice percent of fruit increased sharply up to 01 November and decreased in 01 December (Table 2). Deka *et al.* (2004) observed that juice yield increased with the delayed harvesting. Deka *et al.* (2006) reported that maximum juice yield was recorded in fruits harvested at 250 days after flowering. Similar increase in juice yield with delayed harvesting had also been reported by Joolka and Awasthi (1982) in Kinnow mandarin.

The percent total soluble solids increased considerably with the increase of fruit maturity and it reached the highest (9.4%) when fruits were harvested in 01 December (Table 2). According to Deka *et al.* (2006) linear increase in total soluble solids from 8.93 to 10.03 ^{0}Brix was found in the fruits harvested during 180-230 days after flowering. It decreased to 9.73 at 250 days after flowering. An increase in TSS during fruit development of mandarin was also observed by Joolka and Awasthi (1982) and Raghav and Gupta (2000). Ladaniya

Table 1. Effect of genotype on physical properties of mandarin fruit.

Genotype	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Juice (%)	TSS (%)
CR-Mou 007	103.8 c	5.34 b	5.08 c	45.20	7.7 b
CR-Mou 008	121.9 b	5.59 a	5.58 b	46.73	8.2 a
BARI Komala-1	132.1 a	5.53 ab	6.11 a	47.15	8.2 a
CV (%)	7.83	4.79	4.70	6.89	5.63
Level of significance	**	**	**	**	**

Means in a column followed by the same letters are not significantly different at 1% level of significance, **Significant at 1% level of significance.

Table 2. Effect of date of harvesting on physical properties of mandarin fruit.

Harvesting date (days)	Fruit weight(g)	Fruit length (cm)	Fruit diameter (cm)	Juice (%)	TSS (%)
01 October (200)	103.0 c	5.33	5.34 b	38.16 c	7.0 d
16 October (215)	114.5 b	5.44	5.51 ab	44.08 b	7.2 d
01 November (230)	122.7 ab	5.52	5.66 a	48.55 a	7.9 c
16 November (245)	128.2 a	5.57	5.72 a	50.60 a	8.7 b
01 December (260)	127.9 a	5.57	5.73 a	50.43 a	9.4 a
CV (%)	7.83	4.79	4.70	6.89	5.63
Level of significance	**	**	**	**	**

Means in a column followed by the same letters are not significantly different at 1% level of significance, **Significant at 1% level of significance.

(1996) found minimum 10% TSS in Nagpuri mandarins after 270-280 days from fruit set grown near Nagpur.

Physical properties of mandarin fruits with reference to genotype and harvesting dates

Harvesting time showed significant effect on individual fruit weight, fruit diameter, TSS and juice content of mandarin in all genotype (Table 3). The heaviest (142.5 g) fruit was found in BARI Komala-1 harvested on 16 November, which was statistically identical with fruit harvested at 01 December belongs to the same variety as well as in CR-Mou 008 harvested from 16 November to 01 December. The fruit weight was not increased significantly that might be due to loss of juice and moisture through the fruit rind. The lightest fruit weight (91.21g) was found in CR007 when harvested at 01 October. Fruit diameter was maximum (6.26 cm) in BARI Komala-1 when harvested at 01 December. On the other hand, it was minimum (4.86 cm) in fruits of CR-Mou 007 when harvested at 01 October. The percent juice was highest (52.07%) in BARI Komala-1 at 16 November and it was lowest in CR-Mou 007 (36.66 %) harvested at 01 October. Alferez *et al.* (2003) reported the juice content was relatively higher (61.3%) in early harvested fruit than in late harvested fruit (54.9%). There was a decreasing trend in juice content after 16 November harvesting irrespective of genotype. TSS content of fruit increased with the increase in harvesting time and it was the highest (9.7%) in CR-Mou 008 at 01 December followed by BARI Komala-1 (9.5%) at same harvesting time (Table 3).

Table 3. Combined effect of physical properties of mandarin fruits harvested at different dates.

Genotype	Harvesting date	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Juice (%)	TSS (%)
CR-Mou 007	01 October	91.21 f	5.18	4.86 g	36.66 g	6.8 f
	16 October	100.78 ef	5.30	5.04 fg	43.50 d-f	7.1 ef
	01 November	106.06 ef	5.37	5.14 fg	47.23 a-d	7.6 c-f
	16 November	110.75 de	5.42	5.18 fg	49.52 a-d	8.2 bc
	01 December	110.26 de	5.44	5.18 fg	49.10 a-d	9.0 a
CR-Mou 008	01 October	105.56 ef	5.40	5.29 e-g	39.50 e-g	7.0 f
	16 October	116.22c-e	5.53	5.45 d-f	44.54 b-e	7.2 ef
	01 November	124.55 b-d	5.63	5.68 c-e	48.78 a-d	7.9 c-e
	16 November	131.30 a-c	5.68	5.74 b-e	50.20 a-c	9.1 a
	01 December	131.68 a-c	5.69	5.75 b-e	50.65 ab	9.7 a
BARI Komala-1	01 October	112.14 de	5.41	5.88 a-d	38.31 fg	7.3 d-f
	16 October	126.50 a-d	5.49	6.04 a-c	44.20 c-e	7.4 c-f
	01 November	137.43 ab	5.56	6.15 a-c	49.64 a-c	8.1 cd
	16 November	142.50 a	5.60	6.23 ab	52.07 a	8.9 ab
	01 December	141.76 ab	5.60	6.26 a	51.53 a	9.5 a
CV (%)	-	7.83	4.79	4.70	6.89	5.63
Level of significance		**	NS	**	**	**

Means in a column followed by the same letters are not significantly different at 1% level of significance, **Significant at 1% level of significance, NS = Not Significant.

Chemical properties

The chemical properties of mandarin fruits varied significantly with respect to genotype and harvesting times (Table 4). Total sugar (5.99%), reducing sugar (2.26%) and sugar acid ratio (7.45) were found maximum in fruits of BARI Komala-1 while fruits of CR-Mou 007 contained minimum amount of total sugar (5.37%), reducing sugar (1.86%) and sugar acid ratio (5.60). Quantity of titratable acid and ascorbic acid were highest in CR-Mou 007 (1.07 % and 36.75 mg/100 ml juice, respectively) and lowest in fruits of BARI Komala-1 (0.86 % and 34.46 mg/100 ml juice, respectively). Dris and Jain (2004) reported increased soluble solids and decreased total acids as the mandarin fruits matured gradually.

Table 4. Effect of genotype on chemical properties of mandarin fruit.

Genotype	Total sugar (%)	Reducing sugar (%)	Titratable acid (%)	Ascorbic acid (mg/100 ml juice)	Sugar acid ratio
CR-Mou 007	5.37 c	1.86 c	1.07 a	36.75 a	5.60 c
CR-Mou 008	5.76 b	2.09 b	0.90 b	35.36 b	6.97 b
BARI Komala-1	5.99 a	2.26 a	0.86 b	34.46 b	7.45 a
CV (%)	3.49	6.55	7.60	5.00	3.33
Level of significance	**	**	**	**	**

Means in a column followed by the same letters are not significantly different at 1% level of significance, **Significant at 1% level of significance.

Total sugar and reducing sugar of fruit were increased significantly with the increase of harvesting period (Table 5). Deka *et al.* (2006) reported that reducing sugar in mandarin was increased linearly (2.94-4.06%) with the increase of harvesting period. Titratable acid and ascorbic acid content of mandarin fruit were higher in early harvesting (01 October) and gradually declined with the delayed harvesting (Table 5). It might be due to the conversion of acidic component of fruit into sugar with delayed harvesting. Deka *et al.* (2006) observed that the ascorbic acid content of mandarin decreased from 46.08 to 35.74 mg/100 g at matured green stage to full ripe stage. Sugar acid ratio was increased with the increase of harvesting period (Table 5). Sugar acid ratio (10.34) was higher in the fruit harvested at 01 December (260 days after fruit set). Torres and Castano (1969) reported eight month duration was required for mandarin maturity. Ladaniya (1996) found sugar/acid ratio 14 after 270-280 days from fruit set in Nagpur' mandarin grown near Nagpur.

Total sugar and reducing sugar content of fruit were increased with the increase of harvesting time irrespective of genotypes/variety but titratable acid and ascorbic acid content was in reverse order. The total sugar was more in CR-Mou 008 (7.26 %) and BARI Komala-1 (7.47 %) when harvested at 01 December (Table 6). The highest reducing sugar was also observed in BARI Komala-1 when harvested at 01 December and it was the lowest in CR-Mou 007 when harvested at 01 October. Higher amount of titratable acid and ascorbic acid were found in the genotype CR-Mou 007 when harvested at 01 October and these were lower in BARI Komala-1 when harvested at 01 December (Table 6). Dris and Jain (2004) reported total acids fall from 2.45 to 1.20%, to the point in time when one-third of the fruit developed yellow colour (late September to late October) and subsequent decrease in acids was not so dramatic. The highest sugar acid ratio was observed in BARI Komala-1 when harvested at 01 December. Liu *et al.* (1998) stated the fruit harvested early were of poorer quality than those harvested later. The optimum maturity occurred between 14 and 23 November, while the fruits had about 40% yellow coloration on the rind. Dubey *et al.* (2006) suggested to harvest of Khasi mandarin from the last week of November.

Table 5. Effect of genotype and time of harvesting on chemical properties of mandarin.

Harvesting date (days)	Total sugar (%)	Reducing sugar (%)	Titratable acid (%)	Ascorbic acid (mg/100 ml juice)	Sugar acid ratio
01 October (200)	4.45 e	1.54 d	1.30 a	39.75 a	3.44 e
16 October (215)	4.78 d	1.79 c	1.00 b	38.27 a	4.90 d
01 November (230)	5.42 c	1.88 c	0.95 b	36.21 b	5.66 c
16 November (245)	6.78 b	2.27 b	0.77 c	32.99 c	8.82 b
01 December (260)	7.11 a	2.86 a	0.69 d	30.39 d	10.34 a
CV (%)	3.49	6.55	7.60	5.00	3.33
Level of significance	**	**	**	**	**

Means in a column followed by the same letters are not significantly different at 1% level of significance, **Significant at 1% level of significance.

Table 6. Combined effect of chemical properties of mandarin fruits at different harvesting date.

Genotype	Harvesting date	Total sugar (%)	Reducing sugar (%)	Titratable acid (%)	Ascorbic acid (mg/100 ml juice)	Sugar acid ratio
CR-Mou 007	01 October	4.16 h	1.44 i	1.425 a	41.49 a	2.92 j
	16 October	4.57 g	1.71 gh	1.210 b	39.15 ab	3.78 i
	01 November	5.13 e	1.59 hi	1.160 b	36.84 b-d	4.42 h
	16 November	6.40 c	2.04 ef	0.829 c-e	34.40 d-f	7.72 d
	01 December	6.61 bc	2.52 c	0.721 ef	31.85 f-h	9.17 c
CR-Mou 008	01 October	4.47 gh	1.52 hi	1.266 b	39.36 ab	3.53 i
	16 October	4.78 e-g	1.75 gh	0.954 c	38.60 a-c	5.01 g
	01 November	5.53 d	1.90 fg	0.880 cd	36.21 b-d	6.28 f
	16 November	6.78 b	2.35 cd	0.725 ef	32.46 e-g	9.35 c
	01 December	7.26 a	2.92 b	0.681 f	30.15 gh	10.66 b
BARI Komala-1	01 October	4.72 fg	1.66 g-i	1.220 b	38.40 a-c	3.87 i
	16 October	5.00 ef	1.90 e-g	0.845 c-e	37.05 b-d	5.92 f
	01 November	5.60 d	2.14 de	0.814 de	35.57 c-e	6.88 e
	16 November	7.15 a	2.43 c	0.762 d-f	32.10 f-h	9.38 c
	01 December	7.47 a	3.15 a	0.667 f	29.16 h	11.20 a
CV (%)	-	3.49	6.55	7.60	5.00	3.33
Level of significance		**	**	**	**	**

Means in a column followed by the same letters are not significantly different at 1% level of significance, **Significant at 1% level of significance, NS = Not Significant.

Qualitative characteristics

Harvesting time influenced considerably the qualitative characters of mandarin fruit of all the tested genotype (Table 7). The fruit colour of CR-Mou 007 (Nagpuri), CR-Mou 008 (Khasi) and BARI Komala-1 (Khasi) were found deep green when harvested at 01 October and the colour changed gradually with dealayed harvesting and finally reached orange colour when harvested at 01 December. Juice colour of CR-Mou 007, CR-Mou 008 and BARI Komala-1 was found light orange during 01 October to 16 October but juice colour in all the cultivars turned orange during 01 November to 01 December harvest except BARI Komala-1 which required deep orange colour.

Peeling was difficult during early harvest (01 October to 16 October) and the fruits of CR-Mou 007, CR-Mou 008 and BARI Komala-1 harvested at 01 December were peeled out easily. The fruits of Nagpuri, Khasi and BARI Komala-1 remain sour if harvested at 01 October.

The sweetness increased gradually from medium sweet to sweet, very sweet with the delayed harvesting from 16 October to 01

November and 16 November, respectively. Taste of fruit of Khasi, Nagpuri and BARI Komala-1 also varied with harvesting time. It was very poor at early harvest (01 October) and improved gradually with delayed harvest and finally reached to excellent taste if harvested during 16 November to 01 December. The initial sign of maturity was change in peel colour from green to orange which might be due to chlorophyll degradation and transformation of the chloroplasts into chromoplasts with yellow, orange and red pigments of carotenoids and lycopene (Dris and Jain, 2004). Deka *et al.* (2006) reported that rind colour changed from green (180 days after flowering) to yellow orange (230 days after flowering) and the fruits acquired acceptable colour only after 230 days of flowering. Ferguson (1996) reported the most suitable time for harvesting of mandarin when one-third to two third of the fruit surface turned green into yellow-orange in Croatia. Colour change was accomplished by a change in the chemical composition of the fruit (Dris and Jain, 2004). Xu-Hao Hua *et al.* (2001) reported that mandarin picked in late November showed the best fruit characteristics with best eating quality and longest storage life.

Table 7. Qualitative characteristics of mandarin Chemical properties of mandarin fruits of three tested genotype at different harvesting times.

Genotype	Harvesting date (days)	Fruit colour	Juice sac colour	Peeling quality	Sweetness	Taste
CR-Mou 007	01 October (200)	Deep green	Light orange	Difficult	Sour	Very poor
	16 October (215)	Green	Light orange	Difficult	Medium sweet	Poor
	01 November (230)	Yellowish green	Orange	Moderate	Sweet	Good
	16 November (245)	Greenish yellow	Orange	Moderate	Very sweet	Good
	01 December (260)	Orange yellow	Orange	Easy	Very sweet	Excellent
CR-Mou 008	01 October (200)	Deep green	Light orange	Difficult	Sour	Very poor
	16 October (215)	Green	Light orange	Difficult	Medium sweet	Poor
	01 November (230)	Yellowish green	Orange	Moderate	Sweet	Good
	16 November (245)	Greenish orange	Orange	Moderate	Very sweet	Good
	01 December (260)	Orange	Orange	Easy	Very sweet	Excellent
BARI Komala-1	01 October (200)	Deep green	Light orange	Difficult	Sour	Very poor
	16 October (215)	Green	Orange	Difficult	Medium sweet	Poor
	01 November (230)	Yellowish green	Orange	Moderate	Sweet	Good
	16 November (245)	Greenish orange	Deep Orange	Moderate	Very sweet	Good
	01 December (260)	Orange	Deep Orange	Easy	Very sweet	Excellent

Conclusion

The sign of mandarin maturity was the change in peel colour from green to orange. The peel colour of CR-Mou 007 (Nagpuri), CR-Mou 008 (Khasi) and BARI Komala-1(Khasi) changed gradually from deep green (01 October) to orange colour (01 December) with the delaying of harvesting. BARI Komala-1 produced higher juice content (52.07 %), total sugar (7.47 %), reducing sugar (3.15%) and sugar acid ratio (11.20) in first week of December. Thus better quality mandarin fruits might be obtained if harvested within mid November to 1st week of December with fruit age of 245 to 260 days from fruit set.

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