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Physico-chemical and sensorial attributes of Sikkim mandarin (*Citrus reticulata*)

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In the north-east region 11.7% area is occupied (57.2 thousand ha) by citrus cultivation and it contributes 6.6% (3.6 thousand tonnes) in total citrus production (NHB 2006). A few ecotypes of mandarin (*Citrus reticulata* Blanco) including Sikkim mandarin, Darjeeling mandarin and Khasi mandarin are excellent in quality and have good export potential (Singh 2006). Among north-eastern states, Sikkim contributes only 2% in citrus production by covering 5% area (NHB 2006). The major citrus growing belts of Sikkim are southern part of north district, central part of south Sikkim, central part of east Sikkim and southern part of west Sikkim. Mandarin is mainly grown in the lower hills of Sikkim under the sub-tropical humid climatic conditions with the altitudinal variations of 3 000′–4 200′.

Citrus growing belts come under the heavy rainfall zone. The average rainfall in 4 different belts was 300 cm (north district), 240 cm (south district), 330 cm (east district) and 200 cm (west district). The west and south districts receive relatively less rainfall than east and north districts. The average temperature in these belts is 16–18°C with maximum of 28.5°C and minimum of 5°C and the average humidity is generally 74% with the maximum of 90% and minimum of 50%.

The physico-chemical and sensorial attributes of mandarin cultivated in different areas of Sikkim have not been studied so far. Since these attributes of fruits not only determine the quality of processed products but also quality of planting material. The present investigation aimed to study a variation in the physico-chemical and sensorial attributes of fruits of mandarin in Sikkim.

Fruits were collected from 4 different citrus growing belts of Sikkim during December and analysis was carried out at ICAR Sikkim Centre, Tadong, Gangtok, during 2007–09. Since from each district 2 important citrus growing areas were identified and from each area 4 representative orchards were selected. From each representative orchard 300 fruits were collected from 15 randomly selected healthy plants. The average mean values of physico-chemical and sensorial attributes of 4 orchards were considered as the fruit characters of that area and the average of mean value of attributes of both the areas was considered as the character of mandarin of each district. The areas selected in different districts of Sikkim are: Pasingdang and Loom (north), Sadam and Rabong (south), Central Pandam and Pachak (east) and Dikling and Soreng (west).

The 4 districts were considered as 4 treatments; T_1, north district; T_2, south district; T_3, east district, and T_4, west district. The fruits collected from each orchard graded into 4 categories (I, II, III and IV) on the basis of their weight, and physico-chemical and sensory attributes were studied by taking 25 fruits from each category. The average value of attributes under four categories was considered as the representative attributes of that orchard.

The fruit weight under different categories of fruits was measured by considering mean weight of all the fruits. The juice percentage was calculated by dividing juice content with fruit weight and by multiplying the resultant with 100. The fruit firmness was measured by standard penetrometer (scale 0–10 kg/cm^2). The total soluble solid (TSS) was recorded with ERMA hand refractometer (0–32° Brix). The titrable acidity, vitamin C, reducing sugar and total sugar were determined by following methods of Ranganna (1991). The TSS/acid ratio was calculated by dividing TSS and titrable acidity and similarly sugar/acid ratio was calculated by dividing sugar and acid.

A panel of 6 judges familiar with citrus fruit juice was trained prior to the start of the experiment by use of the triangular test method (ISO 4120, 1983). Flavour profiling (ISO 6564, 4985, 1985) was used to evaluate juices. Flavour descriptive attributes of citrus fruit juice unanimously agreed upon were flavour intensity, sourness, sweetness and overall impression of the juice. Judges were served with coded juice samples at the ambient temperature. The attributes were rated

*Short note

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Table 1 Physical and chemical attributes of Sikkim mandarin

Districts	Fruit weight (g)	Firmness (kg/cm^2)	No. of seeds/fruit	Per cent Juice	TSS (°Brix)	Titrable acidity (%)	TSS/ acid ratio	Vitamin C (mg/100 g)	Reducing sugar (%)	Total sugar (%)	Sugar/ acid ratio
North (T_1)	122.70	0.43	16.40	51.60	11.7	2.20	5.31	34.3	6.00	7.68	3.49
South (T_2)	110.55	0.36	9.49	49.40	11.4	2.42	4.71	39.6	4.83	7.39	3.05
East (T_3)	124.30	0.35	18.50	45.50	12.0	1.74	6.89	32.2	6.20	9.49	5.45
West (T_4)	113.90	0.31	15.70	49.90	10.7	1.34	7.98	28.5	5.84	7.55	5.63
Mean	117.85	0.36	15.01	49.00	11.4	1.96	5.81	33.65	5.7	8.02	3.93
SEM±	3.35	0.02	1.93	1.27	0.27	0.31	0.74	2.31	0.30	0.49	0.66
CD (*P*=0.05)	7.37	0.05	4.24	2.79	0.59	0.68	1.62	5.08	0.66	1.07	1.45

at a 7-point scale (1= imperceptible to 7–very pronounced). A score of 4.0 for flavour intensity, sweetness and overall impression was optimum level below which attributes were considered undesirable while it was the desired level of sourness.

The data recorded on various attributes by taking 3 replicates during the study were statistically analyzed following methods of Panse and Sukhatme (1985). The mean of attributes were compared by paired 't' test and the standard error of mean (SEm) was calculated at 5% level of probability. The correlation between variables was calculated by partial correlation method and the test of significance was considered at 5% and 1% levels of probability.

A significant difference in the fruit weight was observed under different districts (Table 1) with the average fruit weight of 117.8 g of Sikkim mandarin. The maximum fruit weight was recorded in T_3 (east district) while the minimum under T_2 (south district). The fruit weight was in T_1 (north district) was statistically at par with T_4 (west district). The fruit weight of east district was about 12.4% more than that of south district. The low fruit weight in south district and west district may be attributed to moisture stress at the final stage of fruit development, ie during October-November as these districts receive relatively less rainfall. The moisture stress might have reduced the synthesis and translocation of metabolites in fruit cells. The fruit firmness was also recorded (Table 1) and it showed a significant difference between treatments. The maximum firmness of 0.43 kg/cm^2 was recorded in the fruits of north district, while the fruits of west district were relatively soft as it had less firmness (0.31 kg/cm^2). The softness of fruits of west district may be due to more synthesis of polyglacturonose and pectin methyl esterase as they are responsible for solubilization of cell wall (Rahman *et al*. 2008)

The average number of seeds/fruit was studied (Table 1) and it was observed that fruits of east district had the maximum number of seeds, followed by north district. The minimum number of seeds and the lowest seed weight was recorded in the fruits of south district. It is evident from data that number of seeds/fruit in east district was almost double than that of south district and similarly the seed weight/fruit in east district was more than two times of south district. The maximum percentage of juice was recorded in the fruits of north district while the minimum was in east district. The juice content under south district and west district was statistically at a par with the north district. It is evident from data that the physical properties of the fruits were significantly different in 4 districts and the difference could be attributed to variations in the climatic conditions prevailing in different districts. Narayana and Mustaffa (2007) also reported influence of temperature on the shelf-life and chemical properties of banana.

The TSS of juice showed a significant difference between districts with the mean TSS of 11.4° Brix (Table 1). The maximum TSS (12.00° Brix) was recorded in the fruits of east district followed by the fruits of north district while the minimum TSS (10.7° Brix) was recorded in west district. The acidity in fruits of west district was significantly less, and it was about 60% than that south district. The highest titrable acidity was recorded under T_2 (south district), followed by T_1 (north district) while the minimum acidity (1.34%) was recorded under T_4 (west district). The more acidity in the fruit of south district may be due to less synthesis of polyphenol oxidase and peroxidase activities which increased synthesis of organic acid, like citric acid (Kumar and Deo 2004). The highest TSS acid ratio was recorded under T_4 (west district) while lowest under T_2 (south district). The ratio was in intermediate range in north and east districts. The less TSS/acid ratio under T_4 and T_3 was due to low acidity. The ratio under T_4 was 1.69 times more than that of T_2. The TSS/acid ratio is considered as a maturity

Table 2 Chemical attributes of Sikkim mandarin

District	Flavour	Sourness	Sweetness	Overall impression
North	4.15^a	4.20^a	3.65^a	4.48^a
South	3.82^b	4.29^a	3.60^a	3.40^b
East	4.56^c	3.64^b	5.32^b	5.32^c
West	3.90^b	4.22^a	4.12^c	4.82^d

In a column, mean(s) follow by same letter are insignificantly different at 5% LSD

Table 3 Correlation between physico-chemical properties of Sikkim mandarin

Attributes	Fruit weight	Firmness	Seeds/ fruit	Juice (%)	TSS	Acidity	TSS/ Acid	Vitamin C	Reducing sugar	Total sugar	Sugar/ acid ratio
Fruit weight	–										
Firmness	0.084										
seeds/fruit	0.868**	–0.117									
Juice (%)	–0.123	0.814**	–0.133								
TSS	–0.557	–0.036	0.325	–0.254							
Acidity	–0.534	0.428	–0.694*	0.310	0.264						
TSS/Acidity	0.499	–0.541	0.739**	–0.437	–0.053	–0.968**					
Vitamin C	0.540	–0.174	–0.493	0.140	–0.788**	0.021	–0.137				
Reducingsugar	0.31	–0.045	0.665*	–0.255	0.121	–0.588*	0.583*	–0.583*			
Total sugar	–0.015	–0.694*	0.529	–0.870**	0.552	0.386	0.550	–0.438	0.418		
Sugar/Acid	0.469	–0.674*	0.690*	–0.630*	–0.019	–0.918	0.966**	–0.112	0.572	0.703*	

*P=0.05 **P=0.01

index for citrus fruit and the value varies from 6–12 in different citrus species. Similar studies on fruit quality of citrus were conducted by Thatai (2009). The highest vitamin C content was recorded in the fruits of south district, followed by north district. The more vitamin C content (39.6 mg/100 g) in the fruits of south district may be due to more citric acid content as the synthesis of ascorbic acid increases with increase in the citric acid. The data showed that fruits of east district were rich in reducing sugar (6.20%) and total sugar content (9.49%), while south district had minimum reducing sugar (4.83%) and total sugar content (7.39%). The sugar acid ratio was worked out and it was observed that west district had maximum value (5.63), followed by east district (5.45), while south district had the minimum value (3.05). The more sugar acid ratio of west and east districts were due to less acid content and high sugar content. The difference among districts in the chemical attributes may be due to the variations in the changes of primary and secondary metabolites as their synthesis is influenced by temperature and humidity (Ram *et al.* 2004).

Data pertaining to sensorial attributes (Table 2) clearly indicated a significant difference in the flavour intensity between the districts and the fruits of west district possessed highest flavour intensity while south district had the minimum flavour intensity. The flavour intensity depends on the ethanol and ethyl acetate content and with the increase in their content the flavour intensity decreases. The low flavour content in the fruits of south district may be due to the synthesis of metabolic compounds, viz ethanol and ethyl acetate resulting from respiratory metabolism (Marcilla *et al.* 2006). The level of sourness was highest in the fruits of south district while west district had the lowest. Conversely the highest sweetness was recorded in west district and lowest in south district. The overall impression of juice was also observed and it was found that juice of west district had relatively better overall impression.

Table 3 shows the correlation co-efficient between physico-chemical variables. A perusal of data showed that fruit weight was positively correlated (0.868**) with the number of seeds/fruit implying that as the fruit weight increases number of seeds/fruit also increases. Determining a relationship between fruit weight and seeds/fruit is important to predict which fruit may contain more seeds. Table 3 shows that the fruit firmness was positively correlated with the juice content and it can be concluded that fruits having thin peel will have more juice content. The TSS was negatively and significantly correlated with the vitamin C content while vitamin C and acidity were negatively correlated with reducing sugar. Thus it can be concluded that fruits having more TSS will have less vitamin C while fruit having more acidity and vitamin C will have less reducing sugar content and less sweetness. The variables; peel percentage and number of segment/fruit were the most independent, showing the weakest and lowest correlation with other variables.

The TSS and the sugar content of the fruit were positively correlated with sweetness of fruits (0.585). This implies that TSS and sugar can be used as indicators for fruit sweetness. The fruit acidity and vitamin C was positively correlated with sourness of juice (0.854). The flavour of fruit juice was positively correlated with overall impression of juice while other sensorial attributes were not significantly correlated.

SUMMARY

Fruits of east and north districts had more weight and more number of seeds/fruit, while fruits of south district had less weight and least number of seeds. More fruit firmness and the maximum juice percentage were recorded under T_1 (north district). Maximum TSS (12.0° Brix), reducing sugar (6.20%) and total sugar (9.49%) were recorded in the fruits of east district while fruits of west district had poor firmness (0.31 kg/cm^2), minimum acidity (1.34%) and maximum TSS/ acid (7.98) and sugar/acid ratio (5.63). The fruits of south district were highly acidic and had minimum TSS/acid ratio

(4.71) and sugar/acid ratio (3.05). The fruits of west and east districts had more scores for sensorial attributes in respect of flavour, sweetness and overall impression of juice. Fruits from south district had poor sensorial attributes due to more sourness and less sweetness. There was positive correlation between fruit weight and number of seeds/fruit (0.868**) and negative correlation between firmness and peel thickness (–0.578*). And sweetness of fruits increased with increase in TSS and total sugar, the sourness was positively correlated with acidity and vitamin C content.

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