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Studies on physico-mechanical properties of *W. Murcott* mandarin

Jagbir Rehal[1*], Gagan Jyot Kaur[2] and Harsimrat K. Bons[3]

[1]Department of Food Science and Technology, Punjab Agricultural University, Ludhiana- 141004 (Punjab), INDIA
[2] Department of Processing and Food Engineering, Punjab Agricultural University, Ludhiana-141004 (Punjab), INDIA
[3]Department of Fruit Science, Punjab Agricultural University, Ludhiana-141004 (Punjab), INDIA
[*]Corresponding author. E-mail: jagbir@pau.edu

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Abstract: The post-harvest physico-mechanical properties of fruits is important in adoption and design of various handling, packaging, storage and transportation systems. These are important for sizing and grading the fruit before marketing as well as demarcate their end use. Geometric, gravimetric and textural properties were determined for the fresh samples of *W. Murcott* mandarin. The results show that *W. Murcott* fruit diameter varies from 81.82-68.97 mm, equatorial length varies from 86.51-68.43 mm, and length varies from 61.33-52.08 mm. The specific mean area is 57.591 with the sphericity of 0.90. The L, a, b values were 53.37, 42.9 and 49.68 respectively. The firmness varied from 1.351-1.650 kgf. These physical attributes can be taken into consideration while designing the grading and processing equipment.

Keywords: Mandarin, Mechanical properties, Physical properties, *W. murcott*

INTRODUCTION

Citrus is the third major fruit crop of India after banana and mango. It is grown on an area of 1.08 million hectares with a total production of 11.15 million tons (Indian horticulture database, 2014). Among the citrus fruits in India, mandarin is placed at first position with respect to area and production followed by sweet oranges and limes where Punjab produces 9.4% of citrus fruits of India (NHB, 2014). Mandarins are known to exhibit more variation in characters such as fruit weight, fruit diameter, number of seeds, peelability, total soluble solids (TSS), etc.

than other citrus species (Reuther *et al.*, 1967), owing to being the phenotypically heterogeneous group in citrus (Moore, 2001). *W. Murcott* is mid-season variety of mandarin released by Department of Fruit Science, Punjab Agriculture University, Ludhiana in 2013. It matures from 1st to 20th January. The fruit is low seeded in the absence of cross-pollination but it is seedy when cross-pollinated. The flesh is orange, juicy with rich sweet flavor.

W. Murcott (Fig. 1) has good potential for processing into various products like squash, jam etc. as it is moderately seedy with average 10 seeds per fruit in comparison to Kinnow and Daisy which have average 22 and 12 seeds respectively. To design a machine for handling, cleaning, conveying, and storing, the physical, mechanical, and hydraulic properties of agricultural products must be known. The studies on physical properties of various citrus fruits like bergamot (Rafiee *et al.*, 2007; orange (Sharifi *et al.*, 2007); musk lime (Abdullah *et al.*, 2012) etc. is available. The knowledge of *W. Murcott* physical and mechanical properties is hence important to breeders, engineers, food scientists, and processors which will help in further strengthening the citrus industry in India (Singh *et al.*, 2013). Therefore, the present study investigates these properties of *W. Murcott* mandarin.

MATERIALS AND METHODS

W. Murcott fruits were obtained from the department of Fruit Science, Punjab Agricultural University, Ludhiana for the year 2016. Random sampling was done to obtain a representative sample of the harvested produce. The bruised and diseased fruits were sorted out and only sound fruits were selected for the study. The total soluble solids (TSS) content was determined with Erma Hand Refractometer (0-32°B). Titratable acidity was estimated as per AOAC (2000).

Geometric properties: The diameter (b), equatorial width (t) and perpendicular to diameter and equatorial width (l) were measured using a digital vernier caliper (Mitutoyo, model Absolute Digimatic, Japan) precision 0.01mm.The total weight of the fruit was recorded.

The geometric, arithmetic and harmonic mean diameters were evaluated (Mohsenin, 1980) as per equation (1, 2, 3).

Geometric Mean Diameter, $D_g = (btl)^{1/3}$..........................(1)

Arithmetic Mean Diameter, $D_a = (b+t+l)/3$…………....(2)

Harmonic Mean Diameter, $D_h = n/ (1/b+1/t+1/l)$…...(3)

The spherecity (φ) of the fruit was evaluated using the equation (4)

Spherecity, $\varphi = D_g/b$……………………………..………(4)

Surface area: The surface area was calculated on the basis of geometric shape of the fruit. For the mandarin it was calculated using the formula given in equation (5)

$S_f \boxed{= \pi(Dg)^2}$ …..(5)

Where D_g is the geometric mean diameter

Specific surface area: Specific surface area was evaluated by using the equation (6) given by Rich and Teixeira (2005)

$S_{sf}=S_f\, \rho_b / M_{uf}$……………………………………....(6)

S_{sf} = Specific area of the unit fruit (mm^2/cm^3)

$M_{u,F}$, =Mass of one unit of fruit(g)

$\rho_{b,F}$, =Bulk density of fruits(g/cm^3) .

Gravimetric properties: Fruit mass was measured by using electronic balance of 0.1g sensitivity. The bulk density was calculated as the ratio between the mass and the bulk volume of the fruit (Rehal *et al.*, 2012). The true density of the mandarin fruit was determined by water displacement technique. Twenty randomly selected fruits were weighed and taken into a graduated measuring cylinder ensuring that the fruits were submerged in water with the help of a thin rod with a loop at its end. The net volumetric water displacement by each fruit was recorded by using equation (7) (Rehal *et al.*, 2012)

$V_t=M_w/ \rho_w$….(7) where

V_t= True volume(m^3)

M_w=Mass of displaced water (kg)

ρ_w = Density of Water(kg/m^3)

True Density, ρ_t=Wm/Vt where

W_m= Weight of mandarin in air (kg)

V_t= True volume of Mandarin (m^3)

The porosity was calculated from bulk and true densities using the relationship given by Mohesenin((1980), as follows

$\varepsilon = \rho_{t\,-}\, \rho_{b/}\, \rho_{t\ X}\ 100$

where ρ_b is the bulk density and ρ_t is the true density.

Fruit color: The L, a, b values of the fruit were recorded using the Hunter Lab Miniscan XE Plus colorimeter (45/O,10°/D65, Hunter Associates laboratory Inc., Reston, Virginia, USA). In the Hunter scale, 'L' measures lightness and varies from 100 for perfect white to zero for black. The chromaticity dimensions 'a' measures redness when positive, gray when zero and greenness when negative while 'b' measures yellowness when positive, gray when zero and blueness when negative. The Hunter a/b ratio was used as a measure of orange color (Ting and Rouseff, 1986). Four areas along the circumference of each fruit were circled with the help of a marker for the measurement of fruit color. The readings were recorded for the samples brought directly from the field both before and after washing. For each sample, three measurements were taken and averaged.

Texture: One of the basic and most important tests in the study of mechanical properties of fruits and vegetables is the compression test. It can reflect some of the mechanical properties of skin, flesh, and unpeeled products (Jackman and Stanley, 1994; Grotte *et al.*, 2001). Puncture tests are also measures of firmness of fruits and vegetables to estimate harvest maturity or post-harvest evaluation of firmness. Compression and puncture tests were performed by TA-TXi2 Texture Analyser with the load cell of 250 kg to evaluate the firmness of the fresh fruit after picking from the orchard. The mandarin was placed upon a flat plate and ensured that the stem calyx axis was parallel to the flat plate. The p 75 compression plate probe at pre-test speed 2.0 mm/s, test speed 1.0mm/sec, post test speed 2mm/sec, for a distance of 5mm was used for the compression test (Mahajan and Singh, 2014). Puncture test was performed with a 2 mm cylindrical probe at the pre-test speed 2.0 mm/s, test speed 1.0mm/sec, post test speed 2mm/sec, for a distance of 10mm as shown in Fig.2. A sample of 10 fruits (replications) and average values were reported.

RESULTS AND DISCUSSION

The average fruit mass of *W. Murcott* with and without peel was found to be 177.1g and 88.21 g respectively. The TSS(refers to the total amount of soluble constituents of juice which are mainly sugars, with smaller amounts of organic acids, vitamins, proteins, free amino acids, essential oils and glycosides) was found to be 10.8° B with an acidity of 0.68 %. Approximately 85% of the total soluble solids of citrus fruit are sugars, so TSS is an excellent guide to the sugar content of fruit (Hardy and Sanderson, 2010). The peel weight, pomace weight and juice recovery was found to be 50%, 1.34% and 48.66% respectively.

Geometric properties: The dimensional characteristics are important for designing mechanism for harvesting storage and transportation. (Erdo˘gan *et al.*, 2003). The geometric properties such as diameter, equatorial length and length, geometric mean diameter (GMD), arithmetic mean diameter (AMD), harmonic mean diameter (HMD), surface area and specific surface area are tabulated in Table 1. The sphericity of the fruit is calculated as 0.90 (Table 1) which is in the range of

Fig.1: *W. Murcott.*

Fig. 2 (i): *Set up for the Compression Test.*

Fig. 2 (ii): *Set up for the Puncture Test.*

Table 1. Geometric Properties of *W. murcott.*

Geometric Properties	N	Average	Maximum	Minimum	Standard Deviation
Diameter(b) (mm)	20	75.941	81.82	68.97	3.15
Equatorial length (t)(mm)	20	75.323	86.51	68.43	3.99
Length(l) (mm)	20	57.251	61.33	52.08	2.88
GMD(mm)	20	68.90	75.67	65.24	2.77
AMD(mm)	20	69.51	76.52	65.42	2.80
HMD(mm)	20	68.27	74.78	64.58	2.74
Sphericity	20	0.90	0.946	0.867	0.020
Surface Area (cm^2)	20	1.49	1.79	1.33	0.12
Specific surface area	20	57.591	61.60	51.699	2.59

other three cultivars of mandarin (Clementine, Onsho, and Page cultivars) as studied by Khadivi-Khub, 2013).

Gravimetric properties: Gravimetric properties are important for the design of the packaging material and transportation system. It is recorded that the average weight of the *W. Murcott* was 177.1g with a maximum value 236.5g and minimum 150.5g. The average volume is calculated on the basis of geometric mean diameter. It ranged from a maximum of 226.77 to 145.37 cm^3 with an average of 171.99 cm^3.The bulk density and true density is 680.14 kg/m^3 and 750 kg/m^3. The porosity is reported as 0.09.

Color: The color influences the customer acceptability and marketing of the produce. It is observed that “L” (lightness) varies from [0(black) – 100(white)] is higher for the washed samples L (51.33) in comparison to unwashed L(50.41).The coefficient of variance is 0.65. The variation in the values of “a” [measure of red (+ve) – green (-ve)] for washed and unwashed samples are non significant. There is a significant difference in the values of “b” (measure of yellowness) between the washed and unwashed samples as shown in Table3. The coefficient of variance for a and b (washed and unwashed) is recorded as 1.89 and 4.15 respectively. The standard deviation of unwashed samples is higher in comparison to washed samples.

Texture: Texture plays an important role in the quality of the fruit. Compression test was performed to evaluate the ability of the fruit to resist the compression (Fig 2 (i). Fruit firmness is one of the most important attributes in determining the post harvest quality (Lachapelle *et al.*, 2013). Puncture test was performed to evaluated the damage caused due to twig (>5 mm)

Table 2. Gravemetric Properties of *W. Murcott.*

Gravimetric Properties	No. of Fruits	Mean Values (SD)	Maximum Value	Minimum Value
Weight(g)	20	177.12 (21.53)	236.5	150.5
Volume(cm^3)	20	171.99 (21.29)	226.77	145.37

Table 3. Color values of *W. Murcott.*

Color	Washed Fruit	Max. Value	Min. Value	SD	Un-Washed Fruit	Max. Value	Min. Value	SD
L	51.33	54.32	47.36	2.05	50.41	53.37	47.3	2.34
a	35.93	39.77	32.29	1.90	36.71	42.9	32.7	3.54
b	50.26	58.91	45.35	3.40	45.42	49.68	39.34	3.69

Fig. 3. *Fruit showing injury due to larger twig length.*

attached to the fruit (Fig. 3) . The fruit should be harvested with the clipper and should retain a non-protruding short fruit stalk. The average thickness of the twig was 3.4 mm varying from 3.21-3.83 mm. This twig is capable of causing the cavity of average diameter 3.0 mm varying from 2.0-4.31 mm. Considering the thickness of scion, the probe of 2 mm was selected. Puncture test were performed as shown in and Fig. 2. (ii). The greater twig length of the fruit than recommended causes the puncture injury in the adjacent fruits. The thickness of the peel varied from 3.5-4.65 mm. The rupture force varied from 12.046 kgf (min) to 21.178 kgf (max) with an average of 18.385 kgf and is a measure of the strength of the peel and the flesh at the point of the puncture.

The compression force varied from 1.351-1.650kgf with an average of 1.554 kgf which is the measurement of impact of compression of the fruit as a whole. The peak force is 24.025 kgf with an average 22.74 kgf. Similar results were reported by Mahajan and Singh, 2014 who reported a firmness value of 1.821 kgf for control samples during their studies on Kinnow (hybrid of King and Willow leaf (*Citrus nobilis x Citrus deliciosa*).

Conclusion

The sphercity of *W. Murcott* mandarin was 0.90, bulk density was lower than the true density due to the presence of voids (air pockets between individuals). The value of L (Luminosity) and b (hue) was better for washed samples indicating better consumer appeal in comparison to the unwashed sample. It is recommended to wax the washed samples and dry them before packaging as it improves the aesthetic appeal and help in regulating the respiration rate. *W. Murcott* fruit diameter varied from 81.82-68.97 mm, equatorial length varied from 86.51-68.43 mm, and length varies from 61.33-52.08 mm. The specific mean area is 57.591 with the sphericity of 0.90. The L, a, b values were 53.37, 42.9 and 49.68 respectively. The firmness of the mandarin varied from 1.351-1.650kgf. This technical data can be utilized for designing of the grading and processing machines specific for *W. Murcott*.

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