Agronomy Research **16**(S2), 1383–1387, 2018
https://doi.org/10.15159/AR.18.030

3D image analysis of the shapes and dimensions of several tropical fruits

D. Herak[1,*], C. Mizera[1], P. Hrabe[2] and A. Kabutey[1]

[1]Czech University of Life Science Prague, Faculty of Engineering, Department of Mechanical Engineering, Kamycka 129, CZ16521 Prague, Czech Republic
[2]Czech University of Life Science Prague, Faculty of Engineering, Department of Mechanical Engineering, Kamycka 129, CZ16521 Prague, Czech Republic
[*]Correspondence: herak@tf.czu.cz

Abstract. Three dimension virtual models of Avocado (*Persea americana*), Salak (*Salacca zalacca*), Dragon fruit (*Hylocereus undatus*), Mango (*Mangifera indica*), Coconut (*Cocos nucifera*) using 3D scanner Intel RealSense were determined. Calculated models based on arithmetic and geometric diameter were also determined. From statistically analysis implies that virtual models on significance level 0.05 are significantly different with calculated values based on arithmetic or geometric diameter.

Key words: virtual, model, scanner, physical properties.

INTRODUCTION

Accurately understanding to the shapes and dimensions of fruits is one of the key factors which is important for creating mathematical models of their mechanical behaviour (Petrů et al., 2012; Petrů et al., 2014; Herák, 2016). Nowadays with the advent of new progressive technologies the construction process of food processing technologies increasingly utilize 3D virtual models as tools for describing mechanical behaviour of individual fruits as well as bulk fruits (Lizhang et al., 2013; Zhan et al., 2013). These 3D models are usually used in modern simulation processes such are for instance systems based on finite element method (Petrů et al., 2012; Petrů et al., 2014).

Tropical fruits such are Avocado (*Persea americana*), Salak (*Salacca zalacca*), Dragon fruit (*Hylocereus undatus*), Mango (*Mangifera indica*), Coconut (*Cocos nucifera*) are one of the main agricultural products of Southest Asia and they are of great interest to food processors using virtual models to appropriately design the entire food processing chain with respect to high level quality of final products. In previous studies, they were published several 3D models of apple, banana, orange and pear (Barnea et al., 2016). However, the 3D virtual models of tropical fruits which are examined in this study were not described yet in professional literature.

Thus the aim of this research is to determine the three dimension virtual models of Avocado, Salak, Dragon fruit, Mango, Coconut and these virtual models to verify and to compare with real fruits.

MATERIALS AND METHODS

Sample

Avocado (*Persea americana*), Salak (*Salacca zalacca*), Dragon fruit (*Hylocereus undatus*), Mango (*Mangifera indica*), Coconut (*Cocos nucifera*) (Fig. 1) obtained from Medan, Indonesia, were used for the experiment.

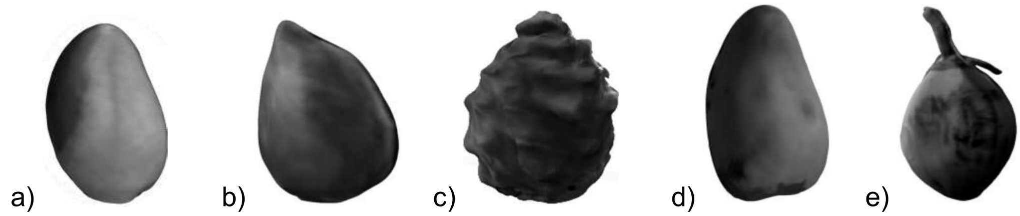

Figure 1. 3D virtual models of Avocado (a); Salak (b); Dragon fruit (c); Mango (d); Coconut (e).

Fruits dimensions

Ten pieces of each fruit were used for determination of dimensions. Dimensions of each fruit, length L (mm), width W (mm), thickness T (mm) were determined by digital calliper (Kmitex 6000.20, Kimtex, Stehelcevs, Czech Republic).

Geometric mean diameter D_g (mm) and arithmetic mean diameter D_a (mm) were calculated using the following equations (Eq. 1; Eq. 2), (Mohsenin, 1970)

$$D_g = \sqrt[3]{W \cdot T \cdot L} \tag{1}$$

$$D_a = \frac{W + T + L}{3} \tag{2}$$

Cross section area based on arithmetic diameter S_a (mm^2) and cross section area based on geometric diameter S_g (mm^2) were calculated by Eq. 3 and Eq. 4.

$$S_a = \frac{1}{4} \cdot \pi \cdot D_a^2 \tag{3}$$

$$S_g = \frac{1}{4} \cdot \pi \cdot D_g^2 \tag{4}$$

Volume based on arithmetic diameter V_a (mm^3) and volume based on geometric diameter V_g (mm^2) were calculated by Eq. 5 and Eq. 6.

$$V_a = \frac{1}{6} \cdot \pi \cdot D_a^3 \tag{5}$$

$$V_g = \frac{1}{6} \cdot \pi \cdot D_g^3 \tag{6}$$

Virtual model

Three dimensional virtual models were created with aid of 3D scanner Intel RealSense. Virtual volumes V_v (mm^3) were determined by Meshmixer (Autodesk Meshmixer, Autodesk Inc., San Rafael, USA). The virtual model is shown in Fig. 2.

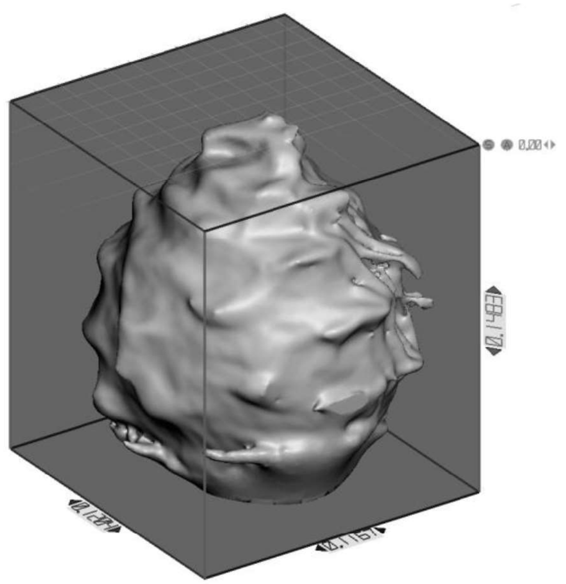

Figure 2. View a virtual model in Meshmixer software.

RESULTS AND DISCUSSION

Measured and calculated dimensions for individual fruits are presented in Table 1. Calculated diameters, volumes and areas are shown in Table 2. From statistical analysis (Table 3) it is evident that determined volumes of virtual models are significantly different on the level of significance 0.05 than calculated models based on arithmetic or geometric diameter. This statement is also clear from the ratio between calculated volumes and virtual volumes such is presented in Table 2.

Table 1. Measured dimensions and calculated diameters, volumes and areas

Fruit	L, mm	W, mm	T, mm	V_v, mm^3
Avocado (SD)	98 (2)	111 (3)	99 (4)	508,049 (16,171)
Salak (SD)	116 (8)	134 (29)	115 (3)	794,008 (174,283)
Dragon fruit (SD)	54 (2)	66 (5)	51 (4)	81,576 (16,750)
Mango (SD)	88 (1)	127 (1)	86 (7)	483,310 (19,745)
Coconut (SD)	160 (4)	242 (43)	164 (10)	2,475,240 (130,480)

Based on measured data (Table 1 and 2), it is evident that 3D models can provide more accurate information about the true geometric properties of the fruit. From these models (Fig. 1) imply that the shapes of the virtual model are similar to shapes of the real fruits and that they can accurately describe surface structures. From determined amounts (Table 1 and 2) it follows that volume standard deviations of analysed fruits except Salak are around fifteen percent which is usual for agricultural products (Mohsenin, 1970). However volume standard deviation of Salak is higher than standard deviation of other analysed fruits that is given by varied and complicated shape which is also evident from Fig. 1c and Fig. 2 (Ismail & Bakar, 2018).

Table 2. Calculated diameters, volumes and areas

Fruit	D_a, mm	D_g, mm	S_a, mm^2	S_g, mm^2	V_a, mm^3	V_g, mm^3	V_a/V	V_g/V
Avocado	103	102	8,263	8,236	565,245	562,418	1.11	1.11
(SD)	(1)	(1)	(178)	(205)	(18,234)	(21,047)	(0.07)	(0.08)
Salak	122	121	11,658	11,581	951,446	941,526	1.20	1.19
(SD)	(13)	(13)	(2,554)	(2,411)	(311,044)	(292,756)	(0.65)	(0.63)
Dragon fruit	57	57	2,555	2,520	97,303	95,308	1.19	1.17
(SD)	(4)	(4)	(319)	(312)	(18,178)	(17,677)	(0.47)	(0.46)
Mango	100	98	7,871	7,596	525,481	498,131	1.09	1.03
(SD)	(1)	(1)	(179)	(175)	(17,946)	(17202)	(0.08)	(0.08)
Coconut	189	185	28,005	26,891	3,529,675	3,319,168	1.43	1.34
(SD)	(10)	(6)	(2,836)	(1,620)	(535,592)	(299,898)	(0.29)	(0.19)

From already published studies as well as from this conducted study follows that these determined 3D virtual models can be used as tools in modern simulation processes such are for instance systems based on finite element method (Petrů et al., 2012; Lizhang et al., 2013; Zhan et al., 2013; Petrů et al., 2014). The benefit in using these models is mainly for accurate simulation of processing, storage and transportation of fruits (Barnea et al., 2016).

Table 3. Statistical analysis measured values with models' values

Compared amount		V_a/V_v	V_g/V_v
T test value	Avocado	9.740	7.803
	Salak	2.296	2.233
	Dragon fruit	2.860	2.539
	Mango	10.752	6.121
	Coconut	4.259	6.630
T test critical value		1.833	1.833

CONCLUSIONS

The three dimension virtual models of Avocado, Salak, Dragon fruit, Mango, Coconut were determined and compared with real fruits. The measured values using standard methods were compared with the values from the models. From statistically analysis implies that this model on significance level 0.05 are significantly different with calculated values based on arithmetic or geometric diameter. Based on measured data, it is evident that 3D models can provide more accurate information about the true geometric properties of the fruit. They can be used, for example, in the construction of machines and equipment for harvesting fruit.

ACKNOWLEDGEMENTS. This paper has been supported by Internal Grant Agency of Faculty of Engineering – Czech University of Life Sciences Prague – IGA 2017: 31130/1312/3111.

REFERENCES

Barnea, E., Mairon, R. & Ben-Shahar, O. 2016. Colour-agnostic shape-based 3D fruit detection for crop harvesting robots. *Biosystems Engineering* **146**, 57–70.

Herák, D. 2016. Image analysis of the shapes and dimensions of Teff seeds (Eragrostis tef). *Agronomy Research* **14**, 1299–1305.

Ismail, N. A. & Bakar, M.F.A. 2018. Salak-Salacca zalacca. In *Exotic Fruits*. pp. 383–390.

Mohsenin, N. 1970. *Physical properties of plant and animial materials. Vol. 1. Structure, physical characterisitics and mechanical properties. Physical properties of plant and animial materials.* New York, Gordon and Breach Science Publishers, 742 pp.

Petrů, M., Novák, O., Herák, D. & Simanjuntak, S. 2012. Finite element method model of the mechanical behaviour of Jatropha curcas L. seed under compression loading. *Biosystems Engineering* **111**, 412–421.

Petrů, M., Novák, O., Herák, D., Mašín, I., Lepšík, P. & Hrabě, P. 2014. Finite element method model of the mechanical behaviour of Jatropha curcas L. bulk seeds under compression loading: Study and 2D modelling of the damage to seeds. *Biosystems Engineering* **127**, 50–66.

Lizhang, X., Yaoming, L., Zheng, M., Zhan, Z. & Chenghong, W. 2013. Theoretical analysis and finite element simulation of a rice kernel obliquely impacted by a threshing tooth. *Biosystems Engineering* **114**, 146–156.

Zhan, Z., Yaoming, L., Zhenwei, L. & Zhiqiang, G. 2013. DEM simulation and physical testing of rice seed impact against a grain loss sensor. *Biosystems Engineering* **116**, 410–419.