Journal of the Saudi Society of Agricultural Sciences (2015) xxx, xxx–xxx

King Saud University

Journal of the Saudi Society of Agricultural Sciences

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FULL LENGTH ARTICLE

Physical properties and mathematical modeling of melon (*Cucumis melo* L.) seeds and kernels

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Received 7 May 2015; revised 29 June 2015; accepted 5 July 2015

KEYWORDS

Dimensional properties;
Image processing technique;
Gravimetric properties;
Frictional properties;
Angle of repose

Abstract In the present research, some physical properties of Somsori and Varamin varieties of melon seeds and kernels were studied; three principal dimensions (length, width and thickness) of melon seeds and kernels were measured using image processing technique. Results indicated that mass of the Somsori and Varamin varieties seeds was equal to 0.043 and 0.052 g, respectively. The corresponding value for melon kernels was found to be 0.031 and 0.036, respectively. True density of the Somsori and Varamin varieties seeds was equal to 1182.612 and 1132.058 kg m^{-3}, respectively. The corresponding value for melon kernels was found to be 1479.731 and 1535.911 kg m^{-3}, respectively. Results showed that with increasing volume of container from 500 mL to 600 mL bulk density of the seeds increased. But with increasing volume of container from 600 mL to 1500 mL, bulk density of the seeds decreased. Also with increasing volume of container from 500 mL to 1000 mL bulk density of the kernels increased. But with increasing volume of container from 1000 mL to 1500 mL, bulk density of the kernels decreased. Values of coefficient of friction of seeds and kernels on rubber surface were more than the iron, galvanized and plywood surfaces, but values of coefficient of friction of seeds and kernels on galvanized surface were less the other surfaces. Comparison between three methods of measuring angle of repose showed that values based on pouring method and filling method were more and less than the other methods, respectively.

1. Introduction

Melon (*Cucumis melo* L.) is a valuable cash crop grown throughout the world. It is a member of the genus *Cucumis*, in the family Cucurbitaceae. *C. melo* includes a diverse group of annual, trailing-vine plants. Melon is one of the popular fruits in the tropical countries. It originated from Iran and Pakistan, mostly grown in the warmer regions of the world (De Mello et al., 2001; Rashid et al., 2011).

In Iran, mainly in Isfahan, Tehran, Khorasan and Fars provinces, farmers grow local varieties of melon namely

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Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.jssas.2015.07.001
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Please cite this article in press as: Mansouri, A. et al., Physical properties and mathematical modeling of melon (*Cucumis melo* L.) seeds and kernels. Journal of the Saudi Society of Agricultural Sciences (2015), http://dx.doi.org/10.1016/j.jssas.2015.07.001

Nomenclature

A_r	angle of repose, Degree	STD	standard deviation
D_A	arithmetic mean diameter, mm	T	thickness of the seeds, mm
D_G	geometric mean diameter, mm	t	thickness of the kernels, mm
E_R	elongation ratio	V	volume of the seeds or kernels, mm^3
F_R	flakiness ratio	W	width of the seeds, mm
H	height of the cone, mm	w	width of the kernels, mm
L	length of the seeds, mm	x_{avr}	mean seeds or kernels dimension, mm
l	length of the kernels, mm	x_i	midpoint of each class
n	number of occurrence	φ	sphericity of seeds or kernels,%
P_a	projected area of seeds or kernels, mm^2	ε	porosity of seeds or kernels,%
R	radius of the cone, mm	ρ_b	bulk density of seeds or kernels, kg m^{-3}
S_A	surface area of the seeds or kernels, mm^2	ρ_t	true density of seeds or kernels, kg m^{-3}

Samsori, Varamin, etc. In addition to a good source of protein, melon seeds are a rich source of vegetable oil varying from 35% to 49% depending on varieties from different regions (De Mello et al., 2001; Mian-hao and Yansong, 2007; Rashid et al., 2011). Despite being a rich source of protein and oil, its seeds are still being classified as waste product (Mian-hao and Yansong, 2007). Several reports have been published on the composition of muskmelon seeds, as well as fatty acid profile showing higher linoleic acid contents, which, though are variety and genotype dependent (Yanty et al., 2008).

In Iran and Pakistan the melon seeds are generally discarded as an agro-waste and can economically be utilized to extract melon oil thus reducing the overall cost of muskmelon oil biodiesel production when compared with conventional vegetable oils (Rashid et al., 2011). In Iran, due to unavailability of suitable machinery for melon seeds post-harvesting operations such as shelling, sorting, sizing, drying, separating seeds and kernels, packing and oil extraction the melon seeds are discarded.

There are limited published literature about genetic, oil extraction, chemical properties and other scientific fields of melon seeds and kernels. The construction of a melon genetic map based primarily on AFLP markers using a backcross population was described (Wang et al., 1997).

Phenolic content and antioxidant activity of methanolic extracts from different parts of melon including leaf, stem, skin, seed and flesh were investigated (Ismail et al., 2010). Characterizations of some nutritional constituents of melon hybrid AF-522 seeds were studied (De Melo et al., 2000).

Mian-hao and Yansong (2007) cited that the seeds of melon hybrid ChunLi contained high percentages of lipids (35.36%) and proteins (29.90%). Hexane-extracted oil had acid, peroxide, iodine and saponification values of 1.51, 3.95, 89.5 and 226.73, respectively.

The physical, mechanical and morphological properties of seeds, grains, fruits, nuts or kernels must be known in order to design or modify the equipment of conveying, sorting, storing, sizing, oil extraction, drying, packing and other processes of agricultural products. Numerous researches have been conducted on physical, mechanical and chemical properties of agricultural products but there is no published literature about physical and mechanical properties of melon seeds and kernels.

Size and shape are important for separator and sorter and can be used to determine the lower size limits of conveyors. Furthermore, the characteristic dimensions allow a calculation of the surface area and volume of grains, important aspects for the modeling of drying and ventilation. Porosity affects the bulk density which is also a necessary factor in the design of dryer, storage and conveyor capacity while the true density is useful to design separation equipment (Sologubik et al., 2013). The angle of repose and coefficient of friction are considered by engineers as important properties for the design of seed containers and other storage structures and accessories. The static friction coefficient limits the maximum inclination angle of conveyor and storage bin. The amount of power requirement for conveyor depends on the magnitude of frictional force. Angle of repose is a useful parameter for the calculation of belt conveyor width and for designing the shape of storage (Sirisomboon et al., 2007).

Due to there is no published literature on physical properties of melon seeds and kernels, the aim of the present study was to (1) measure three principle dimensions and projected area of melon seeds and kernels for two varieties, namely Somsori and Varamin varieties, based on image processing technique and modeling length, width and thickness of seeds and kernels of the varieties, (2) calculate some dimensional properties including geometric mean diameter, arithmetic mean diameter, sphericity, volume and surface area for seeds and kernels of two varieties, (3) measure gravimetrical properties of the melon seeds and kernels including seeds, kernels and shell mass, 1000 seeds, kernels and shells mass, bulk density, true density and porosity of seeds and kernels and (4) measure frictional properties of melon seeds and kernels including coefficient of static friction and angle of repose based on pouring, filling and empting methods for seeds and kernels of two varieties.

2. Materials and methods

2.1. Sample preparation

Two varieties of melons, namely Somsori and Varamin, which are widely cultivated in Iran, were used in the present work. The Somsori variety used in the present research was planted on late April 2012 in local farms of Porzan plain located on

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