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Application of Artificial Neural Networks (ANN) and Image Processing for Prediction of Gravimetrical Properties of Roasted Pistachio Nuts and Kernels

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A R T I C L E I N F O

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A B S T R A C T

Roasting is among the most common methods of nut processing causing physical and chemical changes and ultimately increasing overall acceptance of the product. In this research, the effects of temperature (90, 120 ,and 150°C), time (20, 35 ,and 50 min) ,and roasting air velocity (0.5, 1.5 ,and 2.5 m/s) on gravimetrical properties of pistachio nuts and kernels including unit mass, true density, ounce, uniformity, size and shell percentage were investigated. Gravitational characteristics were measured by experimental and image processing methods. Artificial neural network method was used to predict the relationship between characteristics obtained from experiments and image processing. Volume, unit mass and true density for pistachio nuts were in a range of 1.06 – 1.24 mm^3, 0.92 – 1.08 g and 866.01 - 871.35 kg / m^3, respectively and they were 0.61-0.77 mm^3, 0.53 - 0.67 g and 862.21 - 871.29 kg / m^3 for pistachio kernels. Number of pistachio nuts was found to be 29-32 per ounce and 102-109 per 100 grams. Uniformity of pistachios was in a range of 1.24-1.50 and their average kernel ratio was higher than 50%. Thus, it can be said that, they were of superior quality. Shell percentage of pistachio nuts was in a range of 38.24–41.98%. Results of the study revealed that ,artificial neural network could properly predict volume and mass of pistachio nuts, but, it had not appropriate ability to predict apparent density.

Introduction

Pistachio (*Pistacia vera L.*) is a tropical plant belonging to the *Anacardiasis* family ,and is a species of Pistacia. The genus of pistachio has 13 species, among which only *Pistacia vera* or domestic pistachio is sufficiently large and economically valuable and other species are used as an ornamental plant (Karimi, 2015). Dried fruits are of great importance due to their low volume and high nutritional value, as well as ease of storage and cultivation. According to the Food and Agriculture Organization of the United Nations (2018), Iran is the second pistachio producer in the world with 315151 metric tons of pistachio nut in 2016. It has been reported that consumption of 42 grams of pistachio nuts can reduce stressful reactions in the body. It is also beneficial for health of blood vessels and prevention of heart disease (Karimi, 2015). Fandoghi or Ohadi,

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Akbari, Ahmad Aghaei, Kalleh Ghucchi and Badami are among the most famous varieties of pistachio nuts in Iran. These varieties provide a wide collection of different flavors and colors of nuts and shells, in various shape, size ,and texure for international customers. Different varieties of pistachios in Iran have low unsaturated fatty acids and high aromatic components. So, they are a special choice for fastidious consumers (Donya-e-eqtesad, 2017).

Roasting is one of the most common forms of processing pistachio nuts with the aim of increasing overall acceptance of the products. This process changes and improves the taste, aroma, texture ,and appearance of the nuts. (Ozdemir, 2001). Microstructure of the nuts varies considerably during roasting process. These changes depend on temperature, time ,and air velocity during the process (Harris, 2013). Access to scientific information regarding physical properties of roasted pistachio nuts and kernels is essential for designing of the equipment, transportation, processing, and packaging. Extensive studies have been carried out on measurement of physical properties of agricultural and food materials by experimental and image processing methods (Hsu *et al*., 1991; Kashaninejad *et al*., 2005; Razavi *et al*., 2007a, 2007b; Polat, *et al*., 2007; Razavi *et al.*, 2008; El Masry *et al*., 2009; Maghsoudi *et al*., 2010; Razavi and Edalatian 2011; Nazari Galedar *et al.*, 2011; Ercisli *et al*., 2012; Yazdani *et al.*, 2017); to date, there has been no research on the effect of temperature, time ,and air velocity of roasting on gravimetrical properties of pistachio nuts and kernels. Therefore, this study was conducted to investigate the effect of temperature (90, 120 and 150°C), time (20, 35 and 50 min) ,and air velocity (0.5, 1.5 and 2.5 m/s) on gravimetrical properties of pistachio nuts and kernels (unit mass, true density, ounce, uniformity, size, average kernel ratio ,and shell percentage) applying ANN and image processing for prediction of mentioned characteristics.

Materials and Methods

Sample Preparation

O'hadi (Fandoghi) variety of pistachio nuts was selected for this research. It has a round - shape with light yellow to green kernels, bearing large bunches of green hulled and high splitting nuts. It produces attractive as well as good quality nuts suitable for export (Kashaninejad *et al*., 2011). This cultivar was bought during summer from a local market in Mashhad, Khorasan-Razavi province, Iran. Samples were manually cleaned to remove all external substances. Finally, about 30 kg of pistachio nuts were stored at 4°C until processing. Average weight ratio of kernels and average moisture content of pistachio kernels were equal to 62g/100g and 2.9% (w.b.) ,respectively. Moisture content of pistachio kernels was measured in triplicate using oven drying (105°C for 12 hours). 1 kg of pistachio nuts was soaked in 5L of 20% salt solution for 20min (GoktasSeyhan, 2003). After soaking, the salt solution was separated and was removed by a cloth filter. Roasting of pistachio nuts was performed at three levels of temperature (90, 120 and 150°C), three levels of time (20, 35 and 50 min) ,and three levels of air velocity (0.5, 1.5, and 2.5 m/s) . Totally, 27 different treatments of pistachio nuts were studied. For roasting of pistachio nuts, an electrical oven (CIFS120, Fan Azma Gostar, Tehran, Iran) was used equipped with a controller to adjust air velocity of roasting. Air velocity was measured by an electronic anemometer (AM4205, Lutron company, Taiwan) with an accuracy of 0.1m/s. After roasting, the whole kernels were allowed to cool at room temperature (20±2°C).

Measurement of Gravimetrical Properties

Unit mass

Mass of nuts and kernels of the pistachios was measured using a digital balance (Model AND GF 2000), with an accuracy of 0.01 g.

True density

After calculating volume, actual density of pistachio nuts and kernels (kg/m^3) was obtained based on ratio of unit mass to true volume of the sample (Equation 1):

$$\rho = \frac{M_1}{V} \qquad (1)$$

Ounce

At first, 28.35 g of pistachio nuts were weighted. Then, number of pistachio nuts was counted in 28.35 g of weight (Institute of Standards & Industrial Research of Iran, No. 4920).

Uniformity

100g of pistachio nuts were selected. Among which, 10 biggest and 10 smallest nuts were separated. Uniformity was obtained by division of the weight of 10 large nuts by weight of 10 tiny nuts (Institute of Standards & Industrial Research of Iran, No. 4920).

Size

Number of pistachios in 100g was determined as the size of the samples (Institute of Standards & Industrial Research of Iran, No. 4920).

Average kernel ratio

100g of roasted pistachio nuts were selected. The nuts were separated from the shell. Average kernel ratio was obtained by dividing the weight of obtained kernels by 100 (Institute of Standards & Industrial Research of Iran, No. 4920).

Shell percentage

100g of each sample was separated. Then, kernels were removed ,and weight of pistachio shell was obtained in 100 g of sample.

Determination of gravimetrical properties using image processing

200 g of pistachio nuts were chosen from each sample. To take images from the samples, image processing box was used with dimensions of 38×77×38 cm^3, along with fluorescent lamps, digital camera (Model: Canon IXY 510 IS, 12.1 Mega pixels) , and PC. The camera was placed on a tripod, 47.5 cm away from sample plate. 2D images were prepared for roasted pistachio nuts and kernels. First, images of roasted pistachio nuts and kernels were separated from background image. Then, noises were removed and the images were used to determine image properties. To separate images of roasted nuts and kernels from background image, Paint Bucket Tool in Photoshop CS2 (Version 9) was used. Image parameters were obtained using ImageJ software (1.45s, National Institutes of Health, USA) . Color images were converted into 8-bit and binary images ,and edges of images were determined using the Sobel method (Gonzalez and Woods, 2002).

Artificial neural networks

To determine the relationship between real gravimetrical properties and properties obtained from image processing of roasted pistachio nuts and kernels, nf Tool (ANN) from MATLAB, R2009, Mathworks Inc. was used. In this toolbox, hidden layer has a sigmoidal function and output layer contains a linear function. Levenberg-Marquardt post propagation algorithm was used to train the network. 70% of samples were used for

training, 15% of them were used for validation and 15% of them were used for testing. To determine the relationship between the properties obtained from the experiments and image processing, 5, 10, 15 and 20 neurons were used in hidden layer. Gravimetrical properties resulted from image processing and experimental properties were considered as input and output of neural network, respectively.

In this research, gravimetrical properties (unit mass, true density, ounce, uniformity, size, average kernel ratio ,and shell percentage) of roasted pistachio nuts and kernels were studied as functions of temperature (90, 120, and 150 ^{o}C), time (20, 35 and 50 min) ,and air velocity (0.5, 1.5 and 2.5 m/s).

Statistical analysis

A completely randomized factorial design was used to evaluate the results ,and Analysis of Variance (ANOVA) was carried out to compare mean values. All significant differences were reported at $P \leq 0.05$ level. Minitab statistical software (Minitab Release 16, Minitab Inc., USA) was used for all statistical analyses in the present research. However, MSTATC (Version 1.42, Michigan State University) software was used to determine significant differences. Experiments on gravimetrical properties and image processing were performed in 3 and 25 replications, respectively. Prism software (version 7.03) was used to plot the curves.

Results

Unit mass

Table 1 shows variations in kernel mass of the pistachio nuts and kernels under different conditions of roasting. An increase in the temperature, time ,and air velocity of roasting did not have any significant effect on unit mass of roasted pistachio nuts and kernels ($P > 0.05$). Mass of roasted pistachio nuts and kernels were in a range of 0.92 - 1.08 g and 0.53- 0.67 g, respectively. Kashaninejad, *et al*. (2005) reported that , unit mass of pistachio nuts and kernels of the Ohadi variety were in a range of 1.30- 0.90 and 0.80 and 0.51, respectively. Razavi, *et al*. (2007) reported that, unit mass of pistachio nuts and kernels of Ohadi variety in presence of moisture content of 5.33-34.78% were in a range of 1.68- 1.11 and 0.873-0.547g, respectively.

True density

Table 1 shows apparent density of roasted pistachio nuts and kernels under different conditions of roasting. An increase in the temperature, time ,and air velocity of roasting did not have a significant effect on apparent density of pistachio nuts and kernels ($P > 0.05$). Apparent density of pistachio nuts and kernels were in a range of 866.01-871.35 and 862.21 - 871.29 kg/m^3 ,respectively. Razavi *et al.*, (2007) reported that, true density of nuts and kernels of Ohadi variety in presence of moisture content of 5.33-34.78% were in a range of 860.00 - 869.14 kg/m^3 and 860 - 864.27 kg/m^3,respectively.

Ounce

Table 2 presents the values obtained from measurement of ounce of the pistachio nuts. Results showed that temperature, time ,and air velocity of roasting did not have any significant effect on ounce of pistachio nuts ($P>0.05$). In this research, number of pistachio nuts was in a range of 29-32 in an ounce.

Table 1. The effect of time, temperature and air velocity on the unit mass and true density of roasted pistachio nuts and kernels.

Temperarure (C°)	Time (min)	Air velocity (m/s)	Nut		Kernel	
			Unit mass (g)	True density (kg/m^3)	Unit mass (g)	True density (kg/m^3)
90	20	0.5	0.97±0.03	867.79±1.29	0.63±0.04	866.90
90	20	1.5	0.97±0.01	870.47±0.05	0.55±0.05	862.21
90	20	2.5	0.98±0.02	871.35±1.37	0.63±0.01	871.07
90	35	0.5	1.06±0.02	868.53±2.35	0.61±0.01	868.32
90	35	1.5	0.98±0.05	868.67±0.08	0.62±0.06	869.69
90	35	2.5	0.98±0.03	866.01±1.28	0.63±0.01	868.28
90	50	0.5	0.95±0.03	868.73±2.53	0.62±0.03	869.71
90	50	1.5	0.95±0.01	869.66±1.27	0.59±0.02	869.87
90	50	2.5	1.04±0.00	869.41±1.18	0.58±0.06	868.39
120	20	0.5	1.02±0.05	867.75±1.17	0.62±0.01	866.20
120	20	1.5	1.03±0.02	866.90±0.00	0.67±0.00	866.90
120	20	2.5	0.92±0.02	866.90±2.67	0.53±0.02	870.19
120	35	0.5	1.02±0.08	870.31±2.17	0.62±0.04	866.90
120	35	1.5	1.01±0.03	869.49±1.31	0.64±0.02	869.63
120	35	2.5	0.97±0.00	866.90±0.00	0.60±0.00	868.34
120	50	0.5	0.94±0.02	868.74±2.58	0.58±0.04	863.90
120	50	1.5	1.08±0.06	869.31±1.27	0.62±0.02	869.69
120	50	2.5	0.98±0.00	868.68±2.52	0.61±0.01	866.90
150	20	0.5	1.05±0.00	870.22±2.35	0.63±0.02	866.90
150	20	1.5	1.07±0.03	870.16±2.40	0.63±0.00	869.00
150	20	2.5	1.04±0.04	868.57±2.31	0.64±0.01	866.9
150	35	0.5	0.94±0.02	868.75±2.57	0.62±0.05	866.9
150	35	1.5	1.06±0.07	868.55±2.23	0.65±0.00	866.9
150	35	2.5	0.99±0.03	866.90±0.00	0.60±0.00	871.29
150	50	0.5	1.01±0.00	866.90±2.44	0.58±0.07	869.88
150	50	1.5	1.04±0.00	867.74±1.19	0.62±0.00	864.10
150	50	2.5	0.99±0.01	867.77±3.71	0.58±00	862.69

*Standard deviation was zero

Table 2. The effect of time, temperature and air velocity on the coarseness, size, uniformity, average average kernel ratio and shell percent of roasted pistachio nuts.

Temperarure (C°)	Time (min)	Air velocity (m/s)	Coarseness	Size	Uniformity	Average kernel ratio (%)	Shell percent (%)
90	20	0.5	292±0	103±1	1.43±0.01	59.87±0.64	40.14±0.64
90	20	1.5	313±2	108±1	1.50±0.01	59.06±0.10	40.94±0.10
90	20	2.5	294±2	103±1	1.36±0.05	60.67±1.17	39.33±1.17
90	35	0.5	293±2	103±1	1.40±0.09	60.78±0.60	39.23±0.60
90	35	1.5	291±1	104±0	1.45±0.10	61.18±1.51	38.82±1.51
90	35	2.5	294±2	105±1	1.32±0.05	60.14±0.21	39.86±0.21

Table 2. Continued

90	50	0.5	295±1	103±1	1.29±0.03	60.73±0.18	39.28±0.18
90	50	1.5	295±2	102±0	1.26±0.00	61.20±0.25	38.80±0.25
90	50	2.5	295±1	102±0	1.24±0.05	60.88±0.32	39.13±0.32
120	20	0.5	291±1	102±1	1.27±0.01	60.78±0.13	39.22±0.13
120	20	1.5	295±4	102±1	1.30±0.05	60.96±0.12	39.05±0.12
120	20	2.5	316±1	108±2	1.40±0.10	58.02±0.11	41.98±0.11
120	35	0.5	297±1	105±1	1.28±0.03	60.65±0.21	39.35±0.21
120	35	1.5	295±2	102±1	1.26±0.03	61.65±0.50	38.36±0.50
120	35	2.5	295±1	103±1	1.38±0.05	61.00±0.57	39.00±0.57
120	50	0.5	298±0	103±3	1.29±0.01	60.48±1.03	39.53±1.03
120	50	1.5	301±4	103±0	1.32±0.00	61.23±0.35	38.77±0.35
120	50	2.5	294±0	102±1	1.25±0.01	60.58±0.21	39.15±0.21
150	20	0.5	299±6	106±2	1.28±0.04	60.38±1.03	39.63±1.03
150	20	1.5	297±5	103±0	1.29±0.01	60.40±0.63	39.61±0.63
150	20	2.5	299±7	105±1	1.31±0.01	61.14±0.02	38.87±0.02
150	35	0.5	298±1	105±4	1.30±0.13	61.00±0.14	39.00±0.14
150	35	1.5	300±1	106±1	1.29±0.03	60.86±0.29	39.15±0.59
150	35	2.5	296±0	105±1	1.36±0.00	61.55±0.78	38.45±0.78
150	50	0.5	302±2	109±1	1.30±0.00	61.10±0.41	38.90±0.14
150	50	1.5	291±4	105±1	1.28±0.03	58.02±1.45	38.24±1.45
150	50	2.5	299±1	104±2	1.50±0.52	60.80±0.64	39.20±0.64

Uniformity

Table 2 shows uniformity of pistachio nuts. Uniformity of pistachio nuts was in a range of 1.24 - 1.50. Samples have a high grade ,if uniformity of the samples is equal to 1.5. Results showed that increasing temperature, time and air velocity of roasting did not have any significant effect on uniformity of roasted pistachio nuts (P>0.05).

Size

Table 2 shows size of pistachio nuts under different roasting conditions. Results indicated that increasing temperature, time ,and air velocity of roasting had no significant effect on size of pistachio nuts (P>0.05). Number of pistachio nuts was in a range of 100-109 in 100 g of weight.

Average kernel ratio

Table 2 presents average kernel ratio of roasted pistachio nuts. Results showed that increasing temperature, time ,and air velocity of roasting had no significant effect on average kernel ratio of pistachio nuts (P>0.05). Average kernel ratio of pistachio nuts was in a range of 58.02-61.65%. Considering that, average kernel ratio of the pistachio nuts was more than 50%, it can be said that, pistachio nuts had good quality.

Shell percentage

Table 2 shows shell percentage of roasted pistachio nuts. Shell percentage of pistachio nuts was in a range of 38.24-41.98%. Results indicated that increasing temperature, time ,and air velocity of roasting had no significant effects on shell percentage of roasted pistachio nuts (P>0.05). Razavi, *et al* (2007) reported

that, shell percentage of Fandoghi variety of pistachio nuts was equal to 43.54%.

Image processing and ANN predictions

Unit mass

To predict unit mass of pistachio nuts and kernels, data were collected on surface area and volume (first method) from our previous study (Mohamadi-Moghaddam and Razavi., 2019) and were used as input of the neural network. Results showed that surface area data (correlation coefficient of 0.946, mean square error of 2.1×10^{-4} ,with 5 neurons in hidden layer) as input of the neural network were better than volume data (coefficient correlation of 0.827 ,mean square error of $7.26 \times 10^{-4,}$ with10 neurons in hidden layer). So, it can be used to predict unit mass of pistachio nuts (Fig. 1). To predict unit mass of pistachio kernels, volume data (first method) (coefficient correlation of 0.904, mean square error of $1.98 \times 10^{-4,}$ and 10 neurons in hidden layer) had better results than surface data (correlation coefficient of 0.801, mean square errorof $3.2 \times 10^{-4,}$ and 5 neurons in hidden layer) (Fig. 2).

True density

Volume data (first method) collected from our previous study (Mohamadi-Moghaddam and Razavi, 2019) was used as input to predict true density of roasted pistachio nuts and kernels. Results demonstrated that the ANN was not able to predict true density of pistachio nuts (correlation coefficient of 0.510, mean square error of 1.8×10^{-6} ,and 20 neurons in hidden layer) (Fig. 1) and kernels (coefficient correlation of 0.710, mean square error of $2.4 \times 10^{-6,}$ and15 neurons in hidden layer) (Fig. 2). Unit mass data appeared to be more important for prediction of true density.

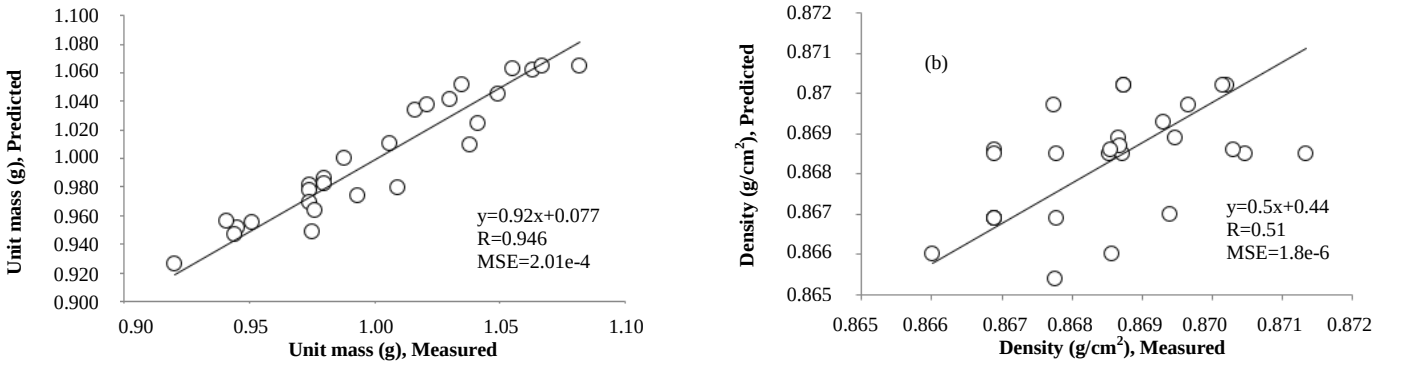

Fig. 1. The predicted values of roasted pistachio nuts by artificial neural network against their experimental values, a) Unit mass, b) true density.

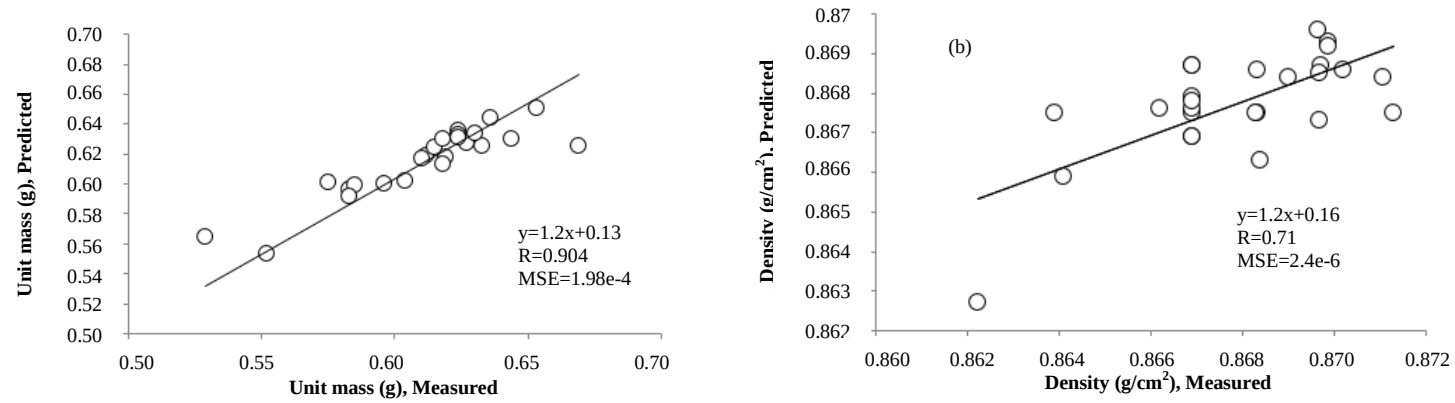

Fig. 2. The predicted values of roasted pistachio kernels by artificial neural network against their experimental values, a) unit mass b) true density

Discussion

Increasing time, temperature and air velocity of roasting did not have any significant effect on unit mass, true density, coarseness, uniformity, size, average kernel ratio and shell percentage. Number of pistachio nuts per ounce and per 100 g and uniformity of pistachios were in the range of 29 - 32, 102-109 and 1.21 - 1.50-1.21, respectively. Results showed that pistachio samples were of superior quality because their grade was higher than 50%. Shell percentage was in a range of 38.24 – 41.98%. An artificial neural network could properly predict unit mass of the pistachio nuts and kernels. The authors declare no conflict of interest.

References

Donya-e-eqtesad (2017) http://donya-e-eqtesad.com/news/441571V

El Masry G, Radwan S, El Amir M, El Gamal R (2009) Investigating the effect of moisture content on some properties of peanut by aid of digital image analysis. Food and Bioproducts Processing. 273 - 281.

Ercisli S, Sayinci B, Kara M, Yildiz C, Ozturk I (2012) Determination of size and shape features of walnut (Juglans regia L.) cultivars using image processing. Scientia Horticulturae. 133(6), 47-55.

FAOSTAT, FAOSTAT Database Results, 2014. <http://faostat.fao.org/site/339/default.aspx>. (2017).

Goktas Seyhan F (2003) Effect of soaking on salting, moisture uptake of pistachio nuts (*Pistachia vera* L.) from Turkiye. Gida / The Journal of Food. 28(4), 395-400.

Gonzalez RC, Woods RE (2002) Digital image processing, 2nd Edition, Pearson Education, Inc., Upper Saddle River, New Jersey, 797.

Harris LJ (Editor) (2013) improving the safety and quality of nuts, Woodhead publishing limited, pp.440.

Hsu MH, Mannapperuma JD, Singh RP (1991) Physical and thermal properties of pistachios. Journal of Agricultural Engineering Research. 49, 311-321.

Institute of Standards & Industrial Research of Iran (1999), Number 4920, Pistachio: test methods.

Karimi HR (2015) Nut fruits (pistachio, almond,walnut, filbert, pecan and cheastnut), Jahad Daneshgahi publication, Mashhad, Iran, 150

Kashaninejad K, Mortazavi A, Safekordi A, Tabil LG (2005) Some physical properties of pistachio (*Pistachio vera* L.) nut and its kernel. Journal of Food Engineering. 72(1), 30–38.

Kashaninejad M, Tabil LG (2011) Pistachio (*Pistacia vera* L.), in Integrated View of Postharvest Biology and Technology of Tropical and Subtropical Fruits, Ed *by E. Yahia*. Woodhead Publishing, ISBN 978-0-85709-090-4. pp. 1-30.

Maghsoudi H, Khoshtaghaza MH, Minaei S (2010) Selected geometric characteristics, density and mechanical properties of unsplit pistachio nut. International Journal of Food Properties. 13, 394–403.

Maghsudi Sh (2010) Pistachio (agricultural, industry, nutrition and treatment). Iran Agricultural Science Publishing Inc., Iran.pp. 134.

Mohamadi-Moghaddam T, Razavi SMA (2019) Application of artificial neural networks (ANN) and image processing for prediction of the geometrical properties of roasted pistachio nuts and kernels. Journal of Nuts. 10(1), 79-93.

Nazari Galedar M, Tabatabaeefar A, Jafari A, Sharifi A, Mohtasebi SS, Fadaei H (2011) Moisture Dependent Geometric and Mechanical

Properties of Wild Pistachio (Pistacia vera L.) Nut and Kernel. International Journal of Food Properties. 13, 1323–1338.

Ozdemir M (2001) Mathematical analysis of color changes and chemical parameters of roasted hazelnuts, Ph.D Thesis, Turkey.

Polat R, Aydin C, Erol Ak B (2007) Some physical and mechanical properties of pistachio nut. Bulgarian Journal of Agricultural Science. 13, 237-246.

Razavi SMA, Edalatian MA (2012) Effect of moisture contents and compression axes on physical and mechanical properties of pistachio kernel. International Journal of Food Properties. 15 (3), 507-517.

Razavi SMA, Emadzadeh B, Rafe A, Mohammad Amini A (2007) The physical properties of pistachio nut and its kernel as a function of moisture content and variety: Part I. Geometrical properties. Journal of Food Engineering. 81, 209–217.

Razavi SMA, Mazaherinasab M, Nickfar F, Sanaeefard H (2008) Physical properties and image analysis of wild pistachio nut (Baneh). Iranian Food Science &Technology Research Journal. 3(2), 61-71.

Razavi SMA, Rafe A, Mohammadi- Moghaddam T, Mohammad Amini A (2007) Physical properties of pistachio nut and its kernel as a function of moisture content and variety. Part II. Gravimetrical properties. Journal of Food Engineering. 81, 218-225.

Yazdani N, Osanloo B, Lotfi M, Asefpour Vakilian K (2017) Application of image processing for investigating the effect of nanozeolite and nanosponge on flesh firmness of cold stored cantaloupe. International Journal of Horticultural Science and Technology. 4(1), 127-133.