Biblid: 1821-4487 (2017) 21; 3; p 154-158 Original Scientific Paper
UDK: 581.48 Originalni naučni rad

MECHANICAL AND CHEMICAL CHANGES IN *MONODORA MYRISTICA* SEEDS AND KERNELS DURING ROASTING

MEHANIČKE I HEMIJSKE PROMENE U SEMENU I ZRNU MONODORA MYRISTICA TOKOM PRŽENJA

Danlami Ibi KWINO, Wilfred Ifeanyi OKONKWO**, Okey Francis OBI***
**College of Agriculture, Department of Agricultural and Bioenvironmental Engineering, Jalingo, Nigeria*
***University of Nigeria, Faculty of Engineering, Dep. of Agricultural and Bioresources Engineering Department, Nsukka, Nigeria*
email: francis.obi@unn.edu.ng

ABSTRACT

The purpose of this paper is to examine changes in the mechanical and chemical properties of Monodora myristica seeds and kernels during roasting. The roasting parameters considered in the experiment encompassed three different roasting air temperatures (140 °C, 170 °C and 200 °C) and four different roasting durations (2, 7, 12 and 17 min.). The mechanical properties of seeds were investigated in two orientations (vertical and horizontal) including the bioyield point, rupture force, deformation at rupture and energy for rupture. The chemical properties included the fat, protein, ash, crude fibre and carbohydrate seed content. On balance, the results obtained indicated that the mechanical properties of Monodora myristica seeds and the chemical properties of Monodora myristica kernels improved with increasing roasting temperatures and durations, with the exception of fat and carbohydrate contents. The roasting parameters significantly influenced (p<0.05) the mechanical properties of the seeds in both vertical and horizontal orientations. The chemical properties of the kernels were significantly affected by the roasting conditions, with the exception of the moisture content.

Keywords: *African nutmeg, mechanical properties, chemical properties, roasting conditions.*

REZIME

Svrha ovog rada je ispitivanje promena u mehaničkim i hemijskim svojstvima semena i zrna Monodora miristica tokom prženja. Parametri prženja, koji su razmatrani u eksperimentu, obuhvatili su tri različite temperature vazduha tokom prženja (140°C, 170°C i 200°C) i četiri različita trajanja prženja (2, 7, 12 i 17 min). Mehaničke osobine semena istraživane su u dve orijentacije (vertikalno i horizontalno), uključujući tačku bioograma, silu razaranja, deformaciju pri razarnju i energiju za razaranje. Hemijske osobine uključuju sadržaj masti, proteina, pepela, sirovih vlakana i ugljenih hidrata. U skladu sa rezultatima, dobijeni podaci ukazuju na to da su mehanička svojstva semena Monodora miristica i hemijska svojstva Monodora miristica zrna poboljšana povišenjem temperature vazduha i trajanja prženja, sa izuzetkom sadržaja masti i ugljenih hidrata. Parametri prženja su značajno uticali (p <0.05) na mehaničke osobine semena u vertikalnim i horizontalnim orijentacijama. Na hemijske osobine zrna značajno su uticale uslovi prženja, sa izuzetkom sadržaja vlage.

Ključne reči: *Afrički muskatni orah, mehaničke osobine, hemijske osobine, uslovi prženja.*

INTRODUCTION

Monodora myristica, otherwise known as the African nutmeg, is a climber tree of the *Anannacea* family which grows well in many tropical forest regions of Africa. *Monodora myristica* seeds, embedded in a white sweet-smelling pulp of the sub-spherical fruit, are economically and medically important as their kernels are a popular condiment, used as a spicing agent in both African and continental cuisines, and an important source of active natural antioxidants (*Okwu, 2004; Burubai et al., 2007*) In many African countries, the bark of the African nutmeg is used for treating a number of ailments such as stomach aches, headaches, hypertension, eye diseases and haemorrhoids (*Koudou et al., 2007*). In addition, *Monodora myristica* kernel flour is used to prepare pepper soups for constipation relief and uterine haemorrhage control in women immediately after childbirth.

Roasting is an important treatment occurring prior to dehulling *Monodora myristica* seeds. The major challenge in the African nutmeg seed processing is cracking the seed coat to extract the kernel, which is still manually extracted using stones. This energy-demanding and time-consuming operation is often accompanied by a thermal treatment to aid the mechanical cracking of the seed (*Burubai et al., 2007*). The effects of roasting on the properties of seeds depend on the balance between the thermal degradation of the properties naturally occurring and the formation of new products (*Açar et al., 2009*). Consequently, the need for a scientific understanding of the influence of thermal processes on the properties of the African nutmeg seeds has received a stronger emphasis. *Kwino et al. (2017)* investigated the effects of the roasting temperature and duration on the physical properties of *Monodora myristica* seeds. The roasting parameters were reported to significantly influence some of the physical properties of the seed. The effects of temperature and moisture content on the strength properties of the African nutmeg (*Monodora myristica*) were reported by *Burubai et al. (2007)*. The effect of roasting conditions on the properties of different seeds have also been argued in the literature (*Sandhu et al., 2015; Zhou et al., 2017; Rocha et al., 2017; Tušek et al., 2015; Oracz and Nebesny, 2016*). Although a number of papers have been published on the effects of roasting conditions on the seed properties, there are practically no studies on the effects of roasting parameters on the mechanical properties of *Monodora myristica* seeds and on the chemical properties of kernels obtained by dehulling the roasted seeds.

The purpose of this study is to determine the effects of roasting duration and temperature on the mechanical properties of *Monodora myristica* seeds and on the chemical properties of kernels recovered after cracking the roasted seeds. The mechanical properties investigated include the bioyield point, rupture force, deformation at rupture, and rupture energy, whereas the chemical properties include fat, protein, ash, crude fibre and carbohydrate contents. This study is particularly important regarding the mechanization of seed processing and exploiting the full economic potential of the end-products obtained.

MATERIALS AND METHODS

Material Preparation

About 24 kg of *Monodora myristica* seeds were purchased at a local market in Nsukka, the Enugu state, Southeast Nigeria and manually cleaned of foreign matters, immature and broken seeds. The initial moisture content, i.e. the wet basis (% w.b.) of seeds was determined using the oven dry method at an air temperature of 103±2 °C until a constant weight was reached (*Kashaninejad et al., 2005*).

Experimental Design

A 3x4 factorial experimental design was employed resulting in 12 experimental samples with four replicates. The experiment included three different roasting temperatures (namely 140 ^{o}C, 170 ^{o}C and 200 ^{o}C) and four different roasting durations (namely 2, 7, 12 and 17 minutes). The 24 kg seed bulk was divided into thirteen parts of 1.5 kg each. The first part was set aside as the control parameter, whereas the other twelve parts were roasted at different combinations of roasting temperatures and durations. The selection of the roasting temperature and duration was based on the conditions found in the literature, which ranged from 100 to 240^{o}C. The seeds were roasted in an electric oven (ELE Limited – Serial no: S80F185-Hemel Hempstead Hertfordshire, England). After roasting, the *Monodora myristica* seeds were allowed to cool down to ambient temperature and each part was further divided into four portions for replications. Sufficient seed quantities were randomly selected from the portions to determine the mechanical properties of the roasted seeds, and cracked manually using a mallet to recover kernels for further chemical property analysis.

Mechanical Properties of the Seed

The effects of the roasting temperature and duration on *Monodora myristica* seed coats were investigated as they affect the seed bioyield point, rupture force, deformation at rupture and energy for rupture. The seeds were roasted in an electric oven, subsequently cooled down to room temperature, and compressed axially and laterally with an electronic tensometer (Hounsfield). The aforementioned mechanical seed properties were recorded by the integrator or recorder chart of the machine. Prior to testing, the seeds were checked for possible cracks, and those with cracks were discarded.

Chemical properties of the kernel

The paper investigates the effects of roasting conditions on the chemical properties of *Monodora myristica* kernels. The following chemical properties of kernels were determined at different combinations of roasting temperatures and durations: moisture content, crude protein, crude fat, crude fibre, ash content, and carbohydrate content. The moisture content was determined as earlier expressed in Equation 1. The protein, fat, fibre and ash content of *Monodora myristica* kernels were determined following the standard methods of analysis (*AOAC, 2005*). The carbohydrate content was calculated by the difference as described in *Ogungbenle (2014).*

Statistical analysis

The experiment was replicated four times at each combination of roasting temperature and duration, and the mean values of the properties investigated were reported. The effects of roasting conditions on the properties of the *Monodora myristica* seeds and kernels were determined by statistically analyzing the data obtained at a 5 % probability level (p<0.05). The analysis of variance (ANOVA) and separation of means by the Duncan multiple range test (DMRT) were carried out using the GenStat analytical software.

RESULTS AND DISCUSSIONS

The roasting air temperature and duration ranged from 140 ^{o}C to 200 ^{o}C, and 2 to 17 min., respectively. Raw *Monodora myristica* seeds and kernels were used as the control parameter in the experiments. Figure 1 shows roasted *Monodora myristica* seeds, and the kernels obtained from roasted seeds.

(a) Roasted seeds (b) Kernels from roasted seeds

Fig. 1. Monodora myristica seeds and kernels

Effect of roasting conditions on the mechanical properties

Mechanical properties of roasted *Monodora Myristica* seeds were investigated in two orientations: vertical (along the length of the seed) and horizontal (along the width of the seed). This is because preliminary investigation carried out revealed that the seed coat was only able to crack without crushing the kernels when compressed in the vertical and horizontal orientation. When the seed is compressed along its width, the seed coat hardly cracked, but when it did, the kernels were crushed inside.

Table 1 displays the mechanical properties of roasted *Monodora Myristica* seeds including the bioyield point, rupture point, deformation at rupture and energy required for rupture determined in the vertical and horizontal orientations. The bioyield point, recorded in the vertical and horizontal orientations of seeds roasted at 140 ^{o}C, 170 ^{o}C and 200^{o}C, generally increased as the roasting duration increased from 2 to 17 min. In the vertical orientation, the bioyield point increased from 250.1 to 317.7 N, 250.8 to 320.8 N and 275.6 to 453.8 N at the 140, 170 and 200^{o}C respectively, as the roasting duration increased from 2 to 17 min. The corresponding bioyield point recorded in the horizontal orientation increased from 300.3 to 361.4 N, 275.2 to 370.0 N and 325.9 to 377.2 N. This suggests that the initial cell rupture in the seed which is usually used as a criterion for maximum allowable load that a seed can sustain without showing any visible damage (*Mohsenin et al., 1965*) increased with increasing roasting conditions.

For the rupture point, which indicates failure over a significant volume of a seed causing fracture planes or cracks in the macrostructure of the seed (*Asoegwu et al., 1995*), no clear trend was observed as the roasting air temperature and duration increased.

The deformation of the seed at rupture was observed to increase as the roasting duration increased at each roasting temperature. This is similar to the result reported by *Burubai et al. (2007)* on the deformation of *Monodora myristica* seeds as a function of the temperature and moisture content. At each roasting condition, the mean deformation recorded in the vertical orientation appeared lower to the corresponding deformation value recorded in the horizontal orientation. The highest mean value of 13.61 mm was recorded in the horizontal orientation of the seed at a temperature 140 ^{o}C and a duration of 17 min., whereas the lowest mean value of 6.0 mm (observed in the vertical orientation of the seed) was recorded at the combined roasting air temperature of 200 ^{o}C and roasting duration of 2 min. The energy or work required to rupture the seed coat appeared to generally increase at each roasting air temperature and duration. However, the increase appeared unsteady in some cases such as in the horizontal orientation of the seed at a temperature of 170 ^{o}C. The observed increase in the energy to rupture the seed coat could be attributed to the general increase in the mean rupture force and the deformation at rupture recorded for the roasted seeds. The mechanical properties determined in this study could be used for different food processing applications including the design of *Monodora Myristica* seed processing machines, quality evaluation and control.

Table 2. Duncan Multiple Range Test for the mechanical properties of Monodora Myristica seeds as influenced by roasting conditions

Parameters	Factor level	Force - Bioyield point (N)		Force - Rupture point (N)		Deformation at rupture (mm)		Rupture energy (J)	
		Vert.	Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.	Horiz.
Roasting air temp., ^{o}C	0	245.9a	288.2a	618.6a	635.0a	15.09a	17.01a	9330.1a	10801.3a
	140	279.0b	327.0b	422.7b	434.7b	8.81b	12.90b	3753.5b	5601.0b
	170	266.6c	320.9b	439.8c	398.8c	8.71b	9.69c	3835.8b	4019.7c
	200	396.7d	351.7c	613.8a	503.6d	6.94c	9.92d	4305.3c	5101.9d
Roasting duration, min	2	253.6a	297.0a	406.2a	448.3a	8.02a	9.11a	3388.7a	4436.7a
	7	298.0b	318.5b	535.3b,c	423.3b	8.29b	11.07b	4317.5b	4794.2b
	12	324.9c	337.5c	524.3b	467.0c	8.60c	11.59c	4521.2c	5451.1c
	17	358.8d	366.1d	541.4c	502.5d	9.83d	13.47d	5282.7d	6762.6d

Vert. – Vertical orientation, Horiz. – Horizontal orientation; Means with different letters for each roasting parameter are significantly different at p<0.05; Roasting air temperature = 0 for raw Monodora myristica seeds

Table 1. Means of the mechanical properties of roasted Monodora Myristica seeds

Roasting air temp (^{o}C)	Roasting duration (min)	Force - Bioyield point (N)		Force -Rupture point (N)		Deformation at rupture (mm)		Rupture energy (J)	
		Vert.	Horiz.	Vert.	Horiz.	Vert.	Horiz.	Vert.	Horiz.
140	2	250.1	300.3	350.9	475.3	8.24	12.08	2890.3	5739.1
	7	262.7	310.6	400.8	401.0	8.02	12.75	3214.6	5113.3
	12	285.3	335.8	468.4	418.9	9.29	13.16	4350.4	5512.4
	17	317.7	361.4	470.8	443.8	9.68	13.61	4557.9	6042.7
170	2	250.8	275.2	450.5	325.2	8.24	4.09	3712.2	1327.9
	7	231.2	300.1	375.7	425.3	8.75	11.52	3287.4	4899.4
	12	263.7	338.3	460.8	400.1	7.74	10.04	3570.8	4015.6
	17	320.8	370.0	472.2	444.7	10.11	13.13	4771.7	5837.3
200	2	275.6	325.9	388.0	500.6	6.00	9.75	2325.4	4881.8
	7	415.7	355.1	800.3	400.1	6.51	7.52	5211.6	3009.7
	12	441.5	348.7	614.5	538.3	7.17	10.19	4406.9	5466.8
	17	453.8	377.2	652.1	575.3	8.10	12.25	5280.0	7047.9

Vert. – Vertical orientation, Horiz. – Horizontal orientation

The data obtained for the mechanical properties of roasted *Monodora myristica* seeds were subjected to ANOVA and the results revealed significant effects ($p<0.05$) of both roasting air temperature and duration on the mechanical properties of the seed in the vertical and horizontal orientations. The means were compared using DMRT, and the results are presented in Table 2. The means recorded for the mechanical properties of the roasted seeds as influenced by the roasting duration were all significantly different ($p<0.05$), with the exception of the rupture force under the vertical loading orientation where the mean value recorded at roasting durations of 7 and 12 min. were not significantly different ($p>0.05$), as well as the means recorded at durations of 7 and 17 min.

Effect of roasting on the chemical properties of *Monodora myristica* kernels

Monodora Myristica kernels were manually obtained from seeds after roasting at different combinations of the roasting air temperature and duration ranging from 140 to 200^{o}C and 2 to 17 min., respectively. Table 3 shows the chemical properties of kernels obtained from the roasted seeds. The chemical properties investigated include the moisture, protein, ash, crude fibre, fats and carbohydrate content. At a roasting temperature of 140 ^{o}C, the moisture content of kernels ranged from 10.05 to 10.08 % (w.b), whereas, at temperatures of 170 ^{o}C and 200 ^{o}C, it ranged from 8.01 to 8.11 % (w.b) and 7.92 to 8.09 % (w.b) respectively as the roasting duration increased. This suggests that upon placing the seeds in the oven at a preset roasting air temperature, the increase in roasting duration from 2 to 17 min. does not appear to produce significant moisture loss in kernels (Table 4). Extended seed roasting for longer periods of time could result in a significant decrease in the kernel moisture content.

The protein content of kernels obtained from the roasted seeds increased steadily as the roasting air temperature and duration increased. The protein content ranged from 12.86 to 16.15 %, 7.03 to 15.13 %, and 11.55 to 16.93 % at the140, 170 and 200oC roasting air temperature level, respectively as the roasting duration increased from 2 to 17 min.

Takeda et al. (2000) reported that the protein content of sesame seeds decreased with an increase in the roasting air temperature. No clear trend was observed in the ash content of the kernels however, the crude fibre content increased in a similar manner as the protein content. The crude fibre content ranged from 38.76 to 48.20 %, 39.60 to 45.31 % and 39.03 to 49.44 % at the 140, 170 and 200^{o}C roasting air temperatures, respectively. An increase in the crude fibre content could possibly be due to the formation of insoluble aggregates with the loss of water due to the roasting process (*Duodu et al., 2003*). The fat and carbohydrate contents were observed to decrease steadily with an increase in the roasting air temperature and duration. At a temperature of 170 ^{o}C, the fat content decreased from 28.02 to 20.24 % while the carbohydrate decreased from 15.38 to 9.03 % as the roasting duration increased. A decrease in the fats and carbohydrates of the seeds could be due to their volatilization under high temperature, which could be responsible for the aroma the kernel produces during roasting. *Sato et al. (2007)* reported that oil oozed out of *Muki* white sesame seeds as roasting air temperature increased forming lumps on the seed surface and deepening the colour of the seed.

Table 3. Means of the chemical properties of kernels obtained from roasted Monodora Myristica seeds

Roasting air temp. (^{o}C)	Roasting duration (min)	Moisture content (% w.b)	Protein (%)	Ash (%)	Crude fibre (%)	Fats (%)	Carbohydrates (%)
140	2	10.05	12.86	2.03	38.76	24.11	12.24
	7	10.05	14.01	2.18	46.80	17.04	10.27
	12	10.05	14.01	2.18	46.80	17.04	10.27
	17	10.08	16.15	2.07	48.20	15.96	7.58
170	2	8.01	7.03	2.03	39.60	28.02	15.38
	7	8.08	12.26	2.04	40.57	24.14	12.93
	12	8.04	14.06	2.13	42.83	22.16	10.90
	17	8.11	15.13	2.09	45.31	20.24	9.03
200	2	8.05	11.55	2.08	39.03	28.92	10.37
	7	7.92	13.26	2.11	44.83	23.12	8.77
	12	8.06	15.32	2.08	46.69	20.18	7.66
	17	8.09	16.93	2.15	49.44	16.11	7.27

Table 4. Duncan Multiple Range Test for the chemical properties of Monodora Myristica kernels obtained from roasted seeds

Parameters	Factor level	Moisture content (% w.b)	Protein (%)	Ash (%)	Crude fibre (%)	Fats (%)	Carbohydrates (%)
Roasting air temp., ^{o}C	0	10.06a	13.65a	3.04a	39.24a	26.04a	9.04a
	140	9.03b	14.26b	2.11b	45.14b	18.53b	10.09b
	170	8.06c	12.12c	2.07b	42.08c	23.64c	12.06c
	200	8.03c	14.26b	2.10b	45.00b	22.08d	8.52d
Roasting duration, min	2	8.73a	10.49a	2.12a	38.76a	27.37a	12.57a
	7	8.71a	13.18b	2.18a,b	43.69b	21.79b	10.57b
	12	8.74a	14.47c	2.20b	45.07c	20.15c	9.52c
	17	8.78a	16.07d	2.17a,b	47.28d	17.79d	7.87d

Means with different letters for each roasting parameter are significantly different at p<0.05;
Roasting air temperature = 0 for raw Monodora myristica seeds

Furthermore, a decrease in the carbohydrate content could be due to caramelization of sugar polysacharides and Maillard reactions accompanying roasting of seeds which reduces the carbohydrates and protein contents of food materials (*Olapade et al., 2012*).

The ANOVA carried out showed that the chemical properties of *Monodora Myristica* kernels were significantly affected ($p<0.05$) by the roasting conditions. The means of the chemical properties were compared using DMRT and the results obtained are shown in Table 4. Table 4 shows that although roasting air temperature significantly affected the kernel moisture content ($p<0.05$), roasting duration had no significant effect ($p>0.05$) on the moisture content of the kernel. The means recorded for the crude fibre, fats and carbohydrates were all significantly different from one another ($p<0.05$) as was influenced by the roasting air temperature and duration. Similar observations were made for the means of the protein content of the kernels. The ash content of the kernels was not significantly affected ($p>0.05$) by the roasting air temperature as it increased from 140 to 200^{o}C, but they were all significantly lower ($p<0.05$) than the ash content of raw *Monodora myristica* kernels.

CONCLUSIONS

The paper examined the effects of roasting conditions (temperature and duration) on the mechanical properties of *Monodora myristica* seeds and on the chemical properties of the kernels recovered after dehulling the roasted seeds. The results obtained revealed that the thermal process of roasting significantly affected the mechanical and chemical properties of the seed and its kernel, respectively. The mechanical properties (bioyield point, rupture point, deformation at rupture, and rupture energy) investigated generally increased as the roasting parameters increased. The following chemical properties, protein, ash and crude fibre content generally increased as the roasting air temperature and duration increased. However, the fat and carbohydrate contents generally decreased with increasing roasting temperatures and durations. The understanding of the influence of roasting air temperature and duration on the mechanical properties of *Monodora myristica* seeds and on the chemical properties of the recovered kernels is useful in designing processing and storing equipment in the quest to mechanize the handling of *Monodora myristica*.

REFERENCES

Açar, Ö.Ç., Gökmen, V., Pellegrini, N., Fogliano, V. (2009). Direct evaluation of the total antioxidant capacity of raw and roasted pulses, nuts and seeds. European Food Research and Technology, 229, 961–969.

AOAC. Official Methods of Analysis 18th ed.; Association of Official Analytical Chemists; Washington DC, 2005.

Asoegwu, S.N., Nwadikom, G.I., Nwammuo, O.P. (1997). Some mechanical properties of plantain fruits. International Agrophysics, 12, 67-77.

Burubai, W., Akor, A.J., Igoni, A.H., Puyate, Y.T. (2007). Effects of temperature and moisture content on the strength properties of African Nutmeg (*Monodora myristica*). International Agrophysics, 21, 217-223.

Duodu, K.G., Taylor, J.R.N., Belton, P.S., Hamaker, B.R. (2003). Factors affecting sorghum protein digestibility. Journal of Cereal Science, 38(2), 117-131.

Koudou, J., Ossibi, A.W.E., Aklikokou, K., Abena, A.A., Gbeassor, M., Bessiere, J.M. (2007). Chemical composition and hypotensive effects of essential oil of *Monodora myristica*. Journal of Biological Sciences, 7(6), 937–942.

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

Kwino, D.I., Okonkwo, W.I., Obi, O.F. (2017). Effects of roasting on the physical properties *Monodora myristica* (African nutmeg). International Food Research Journal, 24(3), 1148-1155.

Mohsenin, N.N., Morrow, C.T., Tukey, L.D. (1965). The yield-point non-destructive technique for predicting firmness of golden delicious apples. Proceeding of American Society of Horticultural Science, 86(1), 70–80.

Ogungbenle, H.N. (2014). Chemical, functional properties and amino acid composition of raw and defatted cashew kernel. American Chemical Science Journal, 4(3), 348-356.

Okwu, D.E. (2004). Phytochemicals and vitamin content of indigenous spices of south eastern Nigeria. Journal of Sustainable Agriculture and the Environment,6, 30-34.

Olapade, A.A., Akinoso, R., Oduwaye, A.O. (2012). Changes in some physicochemical properties of C*assia Sieberiana* seeds during roasting. Nigerian Food Journal, 30(1), 26–34.

Oracz, J., Nebesny, E. (2016). Antioxidant properties of cocoa beans (T*heobroma cacao* l.): influence of cultivar and roasting conditions. International Journal of Food Properties, 19(6), 1242-1258.

Rocha, I.S., de Santana, L.G.R., Soares, S.E., Bispo, E.S. (2017). Effect of the roasting temperature and time of cocoa beans on the sensory characteristics and acceptability of chocolate. Food Science and Technology Campinas, http://dx.doi.org/10.1590/1678-457X.16416

Sandhu, K.S., Godara, P., Kaur, M., Punia, S. (2015). Effect of toasting on physical, functional and antioxidant properties of flour from oat (*Avena sativa* L.) cultivars. Journal of Saudi Society of Agricultural Science, http://doi.org/10.1016/j.jssas.2015.06.004

Sato, E., Watanabe, M., Noda, S., Nishinari, K. (2007). Roasting conditions of sesame seeds and their effect on the mechanical properties of *Gomatofu* (Sesame Tofu). Journal of Home Economics, Japan, 58(8), 471–483.

Takeda, T., Aono, H., Fukuda, Y., Hatae, K., Shimada, A. (2000). Effect of Roasting Conditions on the Food Quality of Sesame Seeds.). Journal of Home Economics, Japan, 51, 1115–1125.

Tušek, A.J., Benković, M., Bauman, I. (2015). Kinetics of colour change in roasted ground coffee during secondary shelf-life. Journal on Processing and Energy in Agriculture, 19(1), 7-11.

Zhou, R., Cai, W., Xu, B. (2017). Phytochemical profiles of black and yellow soybeans as affected by roasting. International Journal of Food Properties, hhttp://dx.doi.org/10.1080/10942912.2017.1280678

Received: 21. 04. 2017. Accepted: 06. 08. 2017.