Atatürk Üniversitesi Ziraat Fakültesi Dergisi
Atatürk University Journal of Agricultural Faculty

Atatürk Üniv. Ziraat Fak. Derg., 51 (3): 219-227, 2020
Atatürk Univ. J. of Agricultural Faculty, 51 (3): 219-227, 2020
ISSN: 1300-9036, E-ISSN: 2651-5016
http://dergipark.gov.tr/ataunizfd

Araştırma Makalesi / Research Article

Physical Characteristics and Nutritional Quality of Chickpea in the Process of Roasted Chickpea Production

Reza ADIBAN[1*,a] Hamid Reza GHASSEMZADEH[2,b] Arash HOSSEINPOUR[3,c]
Farzin Parchami ARAGHI[1,d]

[1] Agricultural Engineering Research Department, Ardabil Agricultural and Natural Resources Research and Education Center, AREEO, Ardabil (Moghan), Iran
[2] Tabriz University, Faculty of Agriculture, Department of Biosystems Engineering, Tabriz, Iran
[3] Crop and Horticultural Science Research Department, Ardabil Agricultural and Natural Resources Research and Education Center, AREEO, Ardabil (Moghan), Iran
*Corresponding autor e-mail: r.adiban@areeo.ac.ir
doi: 10.17097/ataunizfd.629674

Geliş Tarihi (Received): 11.11.2019 Kabul Tarihi (Accepted): 03.08.2020 Yayın Tarihi (Published): 25.09.2020

ABSTRACT: The process of Nokhodchi (roasted chickpea) production includes raw chickpea preparation, First Heat Treatment (FHT), Second Heat Treatment (SHT), Moisture Treatment (MT) and Dehulling and Roasting Treatment (DRT) , respectively. In this study; Time-dependent mechanical behavior of chickpeas under pressure load has been studied based on rheological theories. According to the results of the research, it was determined that the modulus and time of stress relaxation increased from raw chickpea phase to FHT, but decreased from FHT to SHT. It was determined that the module and time of stress relaxation, increased from MT phase to Nokhodchi phase. The volume of Nokhodchi increased by 20% compared to the raw chickpea and showed a lower resistance. The results showed that during the roasting process the crude fat increased, resulting in an increase in the nutritional quality of Nokhodchi.

Keywords: Dehulling, Stress relaxation, Nutritional quality, Roasted chickpea

Kavrulmuş Nohut Üretim Sürecinde Nohudun Fiziksel Özellikleri ve Besinsel Kalitesi

ÖZ: Nokhodchi (kavrulmuş nohut) üretim prosesinde sırası ile çiğ nohut hazırlama, ilk ısıl işlem (FHT), ikinci ısıl işlem (SHT), nemlendirme (MT), kabuk çıkarma ve kavurma (DRT) işlemleri yer almaktadır. Bu çalışmada; nohutun basınç yükü altında zamana bağlı mekanik davranışı, reolojik teorilere dayanılarak incelenmiştir. Araştırma sonuçlarına göre Modül ve gerilme gevşeme zamanının çiğ nohut fazından FHT'yearttığı, ancak FHT'den SHT'ye ise azaldığı tespit edilmiştir. Modül ve stres gevşeme zamanının MT'den Nokhodchi fazına doğru arttığını belirlenmiştir. Nokhodchi'nin hacmi çiğ nohutla karşılaştırıldığında % 20 oranında artmış ve daha düşük direnç göstermiştir. Sonuçlar, kavurma işlemi sırasında ham yağın arttığını ve buna bağlı olarak Nokhodchi'nin beslenme kalitesinde bir artışa neden olduğunu göstermiştir.

Anahtar Kelimeler: Kabuk çıkarma, Stres gevşeme, Besinsel kalite, Kavrulmuş nohut

INTRODUCTION

The chickpea is a valuable source of dietary protein and has significant amounts of vitamins and minerals (Alajaji et al., 2006). The chickpea is classified into two types: Desi and Kabuli, based on shape, size and color. The seeds of Kabuli cultivars are large with white to cream colored seed coat. The seeds of Desi cultivars are small, wrinkled with brown, black or green color. The chickpea seeds are processed and consumed as a variety of products. They are dehusked to chickpea dhal, milled into flour. The chickpea flour is used to prepare a variety of traditional products. Cooking of dhal or whole seeds with spices, sprouting, fermenting, boiling, autoclaving, microwave cooking or roasting, deep-frying pressure cooking (for green seeds as a part of "mixed vegetables"), and canning are some of the major processing technologies employed in utilization of chickpea as food in various parts of the world. (Al-mashat and Zurit, 1993; Bargale et al., 1994; Bargale and Iiudayaraj, 1995; Bhowmlk and Hayakaw, 1993).

Bu makaleye atıfta bulunmak için / To cite this article: Adiban, R., Ghassemzadeh, H.R., Pour, A.H., Araghi, F.P., 2020. Physical Characteristics and Nutritional Quality of Chickpea in the Process of Roasted Chickpea Production. Atatürk Üniv. J. of Agricultural Faculty, 51 (3): 219-227. doi: 10.17097/ataunizfd.629674
[a]ORCID: https://orcid.org/0000-0001-5790-5263 [b]ORCID: https://orcid.org/0000-0001-7101-0060
[c]ORCID: https://orcid.org/0000-0003-2611-8034 [d]ORCID: https://orcid.org/0000-0002-2622-9976

Roasted chickpea is a common nut in several countries of the Middle East. The method of preparation in different countries might be remarkable diversity. However, the industrial processing of Nokhodchi (roasted chickpea) is mainly in Iran, Turkey, and India (Boudeghdegha et al., 2015; Cetin, 2007). In Iran, Nokhodchi production is traditional, and its production equipment have been designed more than 50 years ago. Therefore, designing and constructing of modern equipment is necessary. Low efficiency of dehulling and roasting machines is one of the most important problems of this industry. Development of machines needs to determine the physical characteristics and viscoelastic behavior of the chickpea during each phase of processing. There have been many studies for determining the physical properties of legumes, and in most of these studies, physical properties were studied as a function of moisture (Chavan et al., 1987; Coşkuner and Karababa, 2004; Duar et al., 2008; Ghadge et al., 2008). Konak et al. (2002) studied the physical properties of the chickpea Seeds in three-level moisture content. They found that if moisture content increased, bulk density would decrease and length, width, thickness and geometric would increase.

Koksel et al. (1998) compared the raw and roasted chickpea structures. In this study, scanning electron microscopy was used. Results showed that roasted chickpea has a porous and soft structure compared with raw chickpea. Kaur et al. (2005) studied the features of commonly roasted chickpea in India in two varieties; Desi and Kabuli. They found out that the roasted chickpea volume increase compared with raw chickpea. In roasted chickpea production, chickpeas are subjected to heat treatment in several stages. After heat treatment, water is added in order to increase the moisture content. These stages resulted to changed viscoelastic properties, which increased in elasticity and plasticity. One of the most important viscoelastic features of agricultural materials is stress relaxation. During the stress relaxation test, the specimen suddenly brought to a given strain and stress required to hold the strain constant measured as a function of time (Indian Standard, 2002). Heru et al. (1979) studied soybean's stress relaxation based on the general model of Maxwell. In this experiment, temperature and moisture content factors were introduced as effective parameters on the mechanical behavior of the seed. Khazaee and Maan (2005) studied force relaxation in chickpea. They observed that moisture and series of loading would effect on the mechanical behavior of chickpea. Results indicated a negative correlation between the elasticity module and the moisture.

Long cooking time of the chickpea is a major constraint to wider use of it and can reduce its nutritive value, causing losses of methionine (Shermer and Perkins1975) and reduction in the nutritive value of its proteins (Marquez and Alonso, 1999). Although methods of processing chickpea cause loss protein in it, but the protein quality is preserved by roasting to a higher content than by dry heat treatment. In the other hand, roasting is a high temperature controlled time process known to improve the digestibility, shelf life, and antioxidant properties (Kumar et al., 2020). Exposure at high temperature leads upon roasting to development of characteristic flavor, taste, some nutritional quality and crispy texture in grains that allure the consumers (Jogihalli et al., 2017). The chickpea heat treatment during roasting results increased level of bound fats, which is beneficial for reducing blood cholesterol level largely than raw chickpea in rats (Chavan et al., 1987; Ghribi et al., 2015).

There are some published works about physical properties and nutritional qualities of roasted chickpea; but there is not any research of viscoelastic behavior and changes in nutritional qualities of roasted chickpea in processing. In this study the physical, mechanical and nutritional properties of chickpea during different phases of Nokhodchi preparation, which would help to improve the processing machines.

MATERIAL AND METHOD

Sample Preparing

The study was carried out in a manufacturing workstation in Mamaghan city located in the East-Azerbaijan. The capacity of Nokhodchi processing equipment in the Nokhodchi manufacturing workstation was nearly 50kg. Samples were taken from Nokhodchi during its different processing phases. These processes are shown in Figure 1. First, the raw chickpeas were cleaned from dust, gravel, etc. The optional size of the chickpeas for Nokhodchi production was 8 - 9 mm. In the next step; two-phase heat treatment affected the chickpea's structure and reduced the adhesion of the coat and cotyledon. Then water was sprayed (not soaking) to increase the moisture content to 10%. After 16 or 24-hour relaxation, chickpea was sent to the dehulling and roasting machine. Finally, the output of this phase was called Nokhodchi. The method of sampling was random sampling and it was done at the end of each phase. The moisture of the samples was measured by AOAC method (AOAC, 1980).

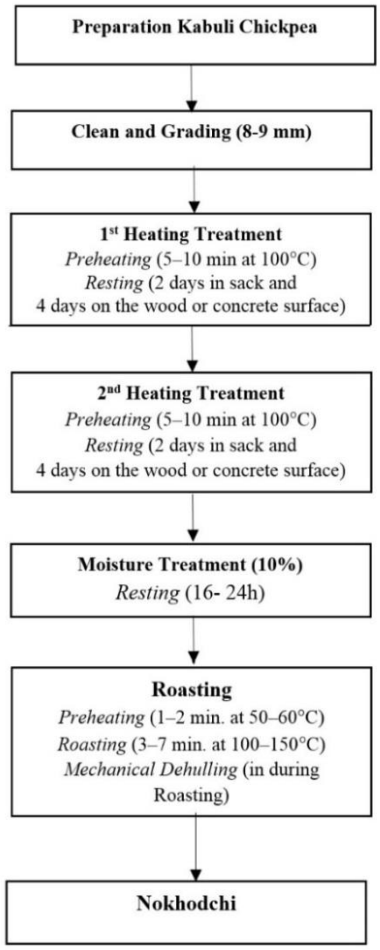

Figure 1. Phases of Nokhodchi processing

Physical properties

The density definition is the ratio between the mass and volume of grains. The average bulk density of treatments in the process was determined by using the standard test weight procedure. A container of 500 ml and height of 150 mm was filled with grain and then was weighted. The volume of grains was determined by using the toluene displacement method. Toluene was used in place of water because it absorbed less water. The volume of displaced was found by immersing a weighed quantity of grains in the toluene (Boudeghdegha et al., 2015; Indian Standard, 2002; Singha and Goswamib, 1996). No separated manual compaction of grains was done. By achieving the volume in the processing phase, puffing and expansion index were determined using E.q (1, 2):

$$\text{Expansion index} = \frac{V_i}{V_r} \quad (1)$$

$$\text{Puffing index} = \frac{V_i - V_r}{V_r} \times 100 \quad (2)$$

Where V_i (ml) is the volume of each phase and V_r (ml) is the volume of raw chickpea.

Viscoelastic behavior

Stress relaxation depends on the structure and moisture of materials. Stress relaxation usually holds asymptotically to a limit value. The behavior of an elastic material is like a spring's, while dashpot measures the behavior of a liquid. Therefore, to investigate the behavior of a viscoelastic material; a device with a combination of spring and dashpot could be considered, and this mechanical collection could be called as a rheological model. This model is useful to show the response of chickpea under stress relaxation. Maxwell's models include a series composition of springs and dashpots, and the general Maxwell model is one of the most important rheological models for describing the behavior of biological materials. This model includes some of Maxwell models and a spring which are connected in parallel (Figure 2).

Figure 2. Zowick/roell texture analyzer machine

When a test sample was taken an immediate strain, the stress reduction with time would be calculated by E.q (3):

$$E(t) = \sum_{i=1}^{n} E_i \, e^{-t/\tau_i} + E_\infty \quad (3)$$

Where E (t) is a decline of the module's function with time and τ_i is the relaxation time. Ei and Ti are the model coefficients. In addition, dashpot coefficients were calculated by $\eta_i = \frac{E_i}{\tau_i}$ equation. The fittest Stress relaxation curve described the rheological behavior of the chickpea (Bargale et al., 1994; Bargale and Iiudayaraj, 1995).

In the relaxation behavior tests of chickpea, the effects of processing phases (raw chickpea, FHT, SHT, MT and roasted chickpea) were studied. The experiments were done by the texture analyzer instrument (Zwick/Roell, Model: BT1-FR2.5TH.D14, Germany). In all the experiments, the loading speed was constant and equivalent to 0.1 mm/s. This loading speed was selected for providing quasi-static conditions. The Chickpea in this test was under the compress of two parallel plates (Figure 3). According to a preliminary test, the strain level (grain deformation on the loading orientation into the primary size) was determined 10%.

After loading, when the strain level in the sample reached by 10%, the loading process was stopped, and force changes with time was stored in memory (300 s). Then the stress was measured by dividing the force into chickpea contact area with a probe. In the next phase, the module-time diagram was drawn by dividing the results of stress data over the constant strain level. The number of the term for Maxwell model was selected according to R^2, RMSE, and MRD ≤ % 5.

Eq. (4) shows the calculation method of MRD (Sandoval et al., 2008; Al-Mashat and Zurit, 1993).

$$\mathrm{MRD} = \max \left| \frac{y_{exp} - y_{cal}}{y_{exp}} \right| \times 100 \quad (4)$$

Where y_{exp} and y_{cal} were the values of the fitted and the experimental models respectively.

Proximate composition

The analyses of ash, crude fat, protein, crude fiber, and carbohydrate were performed using the methods as described by the Association of Official Analytical Chemists (AOAC, 2000).

Statistical analyses

In all the experiments, the means of decathlon observations were reported. The physical properties and the nutritional quality data were analyzed with one-way analysis of variance (ANOVA). The analysis of the means was done by Duncan's test for a significance level of 5%. This data were analyzed using SPSS- 19 software. Also, Calculations and model fitness for viscoelastic behavior were done by MATLAB R2012b software.

RESULTS AND DISCUSSION

For describing the chickpea stress relaxation behavior in different phases, the general model of Maxwell was used. Analyzing module diagrams for a long time showed that the residual spring component (E∞) in Maxwell model is near to zero and it is better not be applied in the model Bargale et al., 1994). Therefore, one-, two- and three-term Maxwell's models for this test were made as following (Eq. 5, 6, and 7):

$$E(t) = E_1 \exp\left(-\frac{t}{\tau_1}\right) \quad (5)$$

$$E(t) = E_1 \exp\left(-\frac{t}{\tau_1}\right) + E_2 \exp\left(-\frac{t}{\tau_2}\right) \quad (6)$$

$$E(t) = E_1 \exp\left(-\frac{t}{\tau_1}\right) + E_2 \exp\left(-\frac{t}{\tau_2}\right) + E_3 \exp\left(-\frac{t}{\tau_3}\right) \quad (7)$$

Where MRD, R^2 and RMSE values for one-, two- and three-term Maxwell's models in different process phases are shown in Table 1. The components for viscoelastic stress relaxation Maxwell models (raw chickpea, FHT, SHT, MT and roasted chickpea) are shown in Table 2. The values of R^2 in three-term Maxwell's model for raw chickpea, FHT, SHT, and roasted chickpea were 0.9887, 0.9944, 0.9957, 0.9906 and 0.9942, respectively. The range of MRD values was between 3.13 and 27.38 for the two-term Maxwell model, and between 12.11 and 59.55 for the one-term model. According to Table 1, the RMSE values decreased while the terms of Maxwell's model increased. Therefore, comparing MRD, R2 and RMSE showed that the three-term Maxwell's model was the best model for describing the rheological behavior of the chickpea during processing. According to the model components in Table 2, the three-term Maxwell's model for DRT was expressed as following.

$$E(t)\ 1.88\exp\left(-\frac{t}{5895}\right)+1.71\exp\ \left(-\frac{t}{19.78}\right)+0.91\exp(-1.98) \quad (7)$$

Figure 4 shows the stress relaxation diagram including experimental data and fitness models (one, two, and three-term) for DRT phase. As could be seen, the three-term Maxwell's model has the best fitness on data.

Table 1. Comparing R2, MRD and RMSE value in one, two-, three- term Maxwell models during chickpea processing

Processing phase	One-term Maxwell model			two-term Maxwell model			three-term Maxwell model		
	MRD (%)	**R^2**	**RMSE**	**MRD (%)**	**R^2**	**RMSE**	**MRD (%)**	**R^2**	**RMSE**
Raw chickpea	18.14	0.6002	0.4944	5.32	0.9649	0.1485	2.09	0.9871	0.0866
FHD	11.66	0.6778	0.2954	3.81	0.9721	0.0884	2.25	0.9944	0.0456
SHD	12.11	0.6354	0.3287	3.13	0.9759	0.0874	1.14	0.9957	0.0480
MT	59.55	0.5025	0.2162	27.38	0.9273	0.0832	4.76	0.9906	0.0381
DRT	16.22	0.7158	0.2047	7.91	0.9731	0.0911	2.59	0.9942	0.0037

Elasticity module component (E1), and time (t1) are the first terms of the Maxwell's three-term model, which were used because of their major contributor to other modules.

Evaluation of elasticity modules in different processing models showed that these values increased from raw chickpea phase to FHT, and decreased from FHT to SHT. The moisture contents of chickpea's treatment decreased during the process of the raw chickpeas to SHT, because of the heat treatment in the kiln (Table 2).

Table 2. Components of one, two and three- term Maxwell models during different processing phases

Processing phase	m.c	One-term Maxwell model		two-term Maxwell model				three-term Maxwell model					
		E_1	τ_1	E_1	τ_1	E_2	τ_2	E_1	τ_1	E_2	τ_2	E_3	τ_3
Raw chickpea	6.8	19.22	2466.15	18.88	3691.15	3.74	7.19	20.77	4388.10	1.64	18.44	1.48	2.96
FHD	6.0	22.02	3911.00	18.39	5788.45	4.68	10.78	21.90	7785.00	1.78	23.77	2.90	2.95
SHD	5.8	19.96	3854.00	18.02	5612.00	2.92	11.08	19.18	7025.00	1.57	21.97	1.61	2.71
MT	8.6	1.61	418.67	1.80	750.30	1.08	11.16	1.44	882.10	1.81	2.56	0.87	1.70
DRT	7.9	1.97	3850.00	1.99	4666.00	1.20	12.14	1.88	5895.00	1.71	19.78	0.91	1.98

Evaluating the elasticity modules in stress relaxation for different grains such as wheat, chickpea and bean in different moisture content indicated that the module values were increased when the moisture contents were reduced (Khazaee and Maan, 2005; Shelef, and Mohsenin, 1967). These increasing trends of modules from the raw chickpea to FHT, which were due to reduced moisture contents, were consistent with cited studies. However, the important issue was the chickpeas restructuring, which was caused by increased plastic properties and reduced elasticity modules during SHT. In fact, the effects of the chickpea restructuring on the module in SHT were greater than the effects of reducing the moisture that caused the reduction of elasticity modules. In MT phase, when the chickpea moisture contents were increased, the elasticity modules showed an obvious decrease (Figure 4).

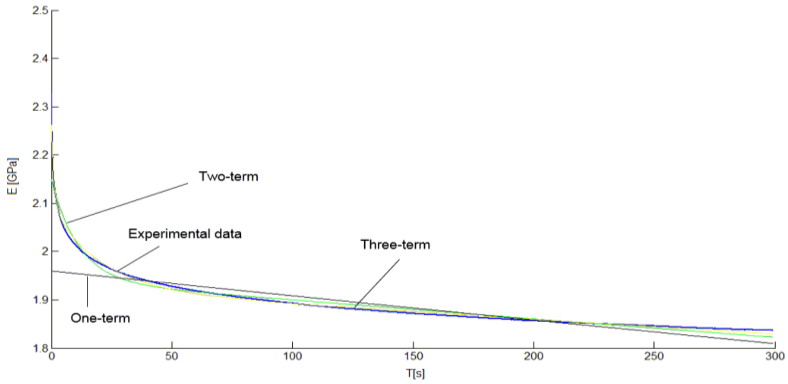

Figure 3. DRT stress relaxation behavior by fitting one, two and three term Maxwell models to experimental data

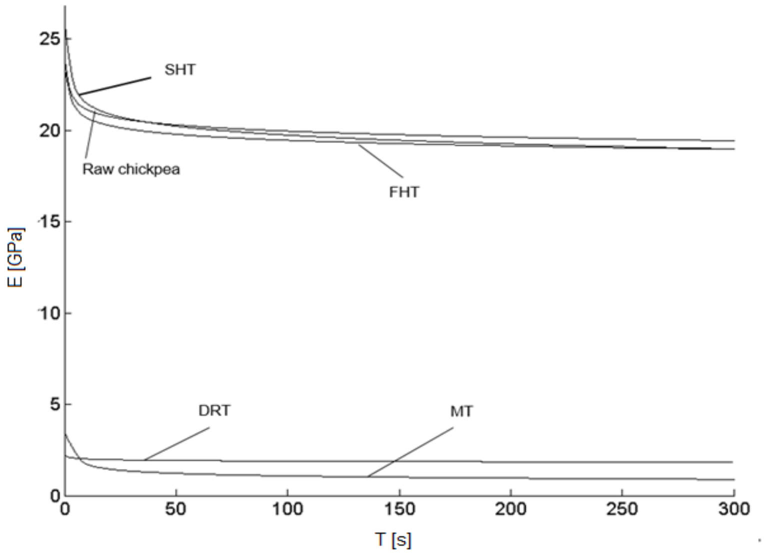

Figure 4. Comparing module- time diagrams for different processing phases

The stress relaxation time from the raw chickpea phase to FHT increased from 4388 to 7785 s, while this value decreased to 7025 s, from FHT to SHT. The increasing value of stress relaxation time is a sign of the increase in viscose property. However, moisture content intensification from SHT phase to MT phase caused an increase in the viscose property and a decrease in stress relaxation time to 882 s. In DRT phase, heat treatment caused moisture content reduction, which increased the stress relaxation time to 5995s. The evaluation of the results showed that the changes of the stress relaxation time were similar to the elasticity modules. Comparing the elasticity modules between SHT and DRT phases showed a high decrease in the DRT phase (from 19.78 to 1.81 that could be in the result of restructuring of the chickpea's cellulose. In fact, heat and moisture treatments increased viscose property and decreased the rigidity of the chickpea, and made a chickpea's structure sufficient for consumption.

Table 3 shows the physical properties of the chickpea processing treatments. Results showed that hardness values increased significantly from raw chickpea phase (365 N) to FHT (386 N). This increase was because of the decrease of the moisture content in FHT phase that could result a stronger cellular compared with the raw chickpea. However, hardness values decreased significantly from FHT to SHT. It could be concluded that the heat was the reason of the changes in the chickpea's cellulose structure and its destruction. The hardness value in moisture treatment was 262. When the moisture content increased, the hardness decreased. In addition, in DRT phase, with roasting heat and dehulling, the hardness value decreased to 45 N. In this phase, the chickpea's cellulose structure was destroyed and Nokhodchi had a lower resistance under compress loading.

The ranges of values for volume, puffing index and expanding index was from 18.01 to 28.45, -0.1 to 2.2 and 0.94 to 1.20, respectively. The results showed that the volume was decreased during FHT and SHT phases and increased during MT and DRT phases. Comparing the characteristics of Nokhodchi and the raw chickpea showed that the final product had by 20% the volume development and resistance reduction. Therefore, this processing system made the product more useful and gave a longer storage property to it.

Table 3. Physical properties of different treatments

Treatment	Hardness[N]	Bulk density [g/ml]	Seed volume [ml/100 seeds]	Puffing Index (%)	Expansion index
Raw chickpea	365.12±7.31a	0.734±0.03a	19.23±1.80a	0a	1a
FHT	386.61±6.77b	0.742±0.05b	18.14±0.90a	-0.1±0.026b	0.94±0.022b
SHT	306.61±6.77c	0.721±0.05b	18.01±0.88a	-0.1±0.016b	0.94±0.012b
MR	262±8.80d	0.627±0.06b	28.45±1.19b	13.9±1.11c	1.40±0.039c
DRT	45.76±1.77e	0.526±0.02b	23.12±1.10c	20.2±1.10d	1.20±0.022d

Table 4 shows the chemical composition of the chickpea's different processing phases. The ash content of chickpea in different processing phases varied from 3.06% to 3.12%. The lowest content was in DRT phase and highest for the raw chickpea. As shown, the heat and the moisture treatments increased the crude fat. Results revealed that roasted chickpea is nutritionally better in raw chickpea. Also, other researchers have reported an increasing trend in Crude fat in the roasting process (Kaur et al., 2005; Kasturiba et al., 1990). During the roasting process, the water inside the chickpea changes from liquid to vapor. The protein content of the chickpeas different treatments were between 19.01% and 19.81%. The protein content decreased during the roasting process. In addition, the observed difference of protein content between raw chickpea and DRT was significant. Daur et al., (2008) reported protein content of 20.13% for roasted chickpea (cv CM-72). Kaur et al., (2005) reported protein content of 16.1–21.3% for five Desi and one Kabuli chickpea cultivars. The reduce in protein content of roasting was found to be in accordance with the results reported by Kumar et al., (2020) for the roasting of black chickpea. The content of crude fiber for different treatments varied from 4.68- 4.72%. Therefore, roasting resulted in a reduction of protein content and might be due to the denaturation of protein and loss of nitrogenous volatile compounds at high temperature (Wani et al., 2017). Crude fiber content reduction during processing was not significant. The carbohydrate composition changed from 66.21% to 66.90%, which was in the total carbohydrate range of the chickpea seeds (52.4 to 70.9%) (Chavan et al., 1987). The findings were supported by Liao et al. (2019) for roasting of cashew nut kernels. They reported an increase in carbohydrate content associated with high temperate of roasting.

Table 4. Chemical composition of different treatments

Treatment	Ash (%)	Crude fat (%)	Protein (%)	Crude fiber (%)	Carbohydrate (%)
Raw chickpea	3.12±0.09a	6.14±0.24a	19.81±0.24a	4.72±0.47a	66.21±1.03a
FHT	3.10±0.17a	6.24±0.24a	19.72±0.36a	4.70±0.37a	66.24±1.14a
SHT	3.13±0.10a	6.30±0.24a	19.60±0.13a	4.71±0.29a	66.26±0.95a
MR	3.09±0.09a	6.31±0.24a	19.12±0.31a	4.68±0.35a	66.80±1.10a
DRT	3.06±0.11a	6.40±0.20a	19.01±0.38b	4.63±0.58a	66.90±0.93a

ACKNOWLEDGMENTS

We would like to thank the anonymous reviewers for their valuable comments and suggestions to improve the manuscript.

Statement of Conflict of Interest

The authors declare that they have no conflict of interest.

Authors' Contribution

RA; Conceptualization, visualization, methodology, software, validation, formal analysis, resources, writing-original draft preparation, HRG; data curation, investigation, AH and FPA; writing-review and editing.

REFERENCES

Alajaji, S.A., El-Adawy, T.A., 2006. Nutritional composition of chickpea (*Cicer arietinum* L.) as affected by microwave cooking and other traditional cooking methods. Journal of Food Composition and Analysis, 19 (8): 806-812.

Al-Mashat, S.H., Zuritz, C.A., 1993. Stress relaxation behavior of apple pomace and effect of temperature, pressing aid and compaction rate on juice yield. Journal of Food Engineering, 20 (3): 247-266.

AOAC, 1980. “Official Methods of Analysis” 13th ed. Association of Official Analytical Chemists, Washington, DC.

AOAC, 2000. “Official Methods of Analysis”. Association of Official Analytical Chemists, Washington, DC.

Bargale, P.C., Irudayaraj, J.M., Marquis, B., 1994. Some mechanical properties and stress relaxation characteristics of lentils. Canadian Agriculture Engineering, 36 (4): 247-255.

Bargale, P.C., Irudayaraj, J., 1995. Mechanical strength and rheological behavior of barley kernels International Journal of Food Science & Technology, 30 (5): 609-623.

Bhowmik, S. R., Hayakawa, K. I., 1983. Influence of selected thermal processing conditions on steam consumption and on mass average sterilizing valuesournal of Food Science, 48 (1): 212-216.

Boudeghdegh, K., Diella, V., Bernasconi, A., Roula, A., Amirouche, Y., 2015. Composition effects on the whiteness and physical-mechanical properties of traditional sanitary-ware glaze. Journal of the European Ceramic Society, (13): 3735-3741.

Cetin, M., 2007. Physical properties of barbunia bean (*Phaseolus vulgaris* L. cv. ‘Barbunia’) seed. Journal of Food Engineering, 80 (1): 353-358.

Chandrashekar, M., Heather., W.A., 1981. "The effect of pre-and post-inoculation temperature on resistance in certain cultivars of poplar to races of Melampsora larici-populina kleb Euphytica., 30 (1): 113-120.

Chavan, J.K., Kadam, S.S., Salunkhe, D.K., Beuchat, L.R., 1987. Biochemistry and technology of chickpea (*Cicer arietinum* L.) seeds. Critical Reviews in Food Science and Nutrition, (2): 107-158.

Coşkuner, Y., Karababa, E., 2004. Leblebi: a roasted chickpea product as a traditional Turkish snack food. Food Reviews International, 20 (3): 257-274.

Daur, I., Khan, I.A., Jahangir, M., 2008. Nutritional quality of roasted and pressure-cooked chickpea compared to raw (*Cicer arietinum* L.) seeds. Sarhad Journal of Agriculture, 24 (1): 117-123.

Ghadge, P.N., Vairagar, P.R., Prasad, K., 2008. Physical properties of chickpea split (*Cicer arietinum* L.). Agricultural Engineering International: CIGR Journal, 10: 10-17.

Ghribi, A.M., Maklouf, I., Blecker, C., Attia, H., Besbes, S., 2015. Nutritional and compositional study of Desi and Kabuli chickpea (*Cicer arietinum* L.) flours from Tunisian cultivars. Adv Nutritional Science and Food Technology, 1 (2): 38-47.

Herum, F.L., Mensah, J.K., Barre, H.J., Majidzadeh, K., 1979. Viscoelastic behavior of soybeans due to temperature and moisture content. Transactions of the ASAE, 22 (5): 1219-1224.

Indian Standard, 2002. Method of analysis of Food Grains, 4333 (Part 3).

Jogihalli, P., Singh, L., Kumar, K., Sharanagat, V.S. 2017. Novel continuous roasting of chickpea (*Cicer arietinum*): Study on physico- functional, antioxidant and roasting characteristics. LWT Food Science and Technology, 86: 456– 464.

Kasturiba, B., Yamannavar, P.Y., Patil, J.S., Parameshwarappa, R., Surendra, H.S., 1990. Nutritional evaluation of gram (*Cicer arietinum*). Orissa. Journal of Agricultural Research, 3: 64-66.

Kaur, M., Singh, N., Sodhi, N.S., 2005. Physicochemical, cooking, textural and roasting characteristics of chickpea (*Cicer arietinum* L.) cultivars. Journal of Food Engineering, 69 (4): 511-517.

Khazaei, J., Mann, D.D. 2005. Effects of moisture content and the number of loadings on force relaxation behavior of chickpea kernels. International Agrophysics, 19 (4): 305.

Köksel, H., Sivri, D., Scanlon, M. G., Bushuk, W., 1998. Comparison of physical properties of raw and roasted chickpea (leblebi). Food Research International, 31 (9): 659-665.

Konak, M., Carman, K., Aydin, C., 2002. Physical properties of chickpea seeds. Biosystems Engineering, 82 (1): 73-78.

Kumar, Y., Sharanagat, V.S., Singh, L., Mani, S., 2020. Effect of germination and roasting on the proximate composition, total phenolics, and functional properties of black chickpea (Cicer arietinum). Legume Science, 2 (1): 20-31.

Liao, M., Zhao, Y., Xu, Y., Gong, C., Jiao, S., 2019. Effects of hot air-assisted radio frequency roasting on nutritional quality and aroma composition of cashew nut kernels. LWT- Food Science and Technology, 116: 108551-108570.

Marquez, M.C., Alonso, R., 1999. Inactivation of trypsin inhibitor in chickpea. Journal of Food Composition and Analysis, 12 (3): 211-217.

Sandoval, E.R., Quintero, A.F. Cuvelier, G., 2009. Stress relaxation of reconstituted cassava dough.

LWT- Food Science and Technology, 42: 202-206.

Shelef, L., Mohsenin, N.N., 1967. Evaluation of the modulus of elasticity of wheat grains. Cereal Chemical, 44 (4): 392-402.

Shemer, M., Perkins, E.G., 1975. Degradation of methionine in heated soybean protein and the formation of beta.-methylmercaptopropionaldehyde. Journal of Agriculture Food Chemical, 23 (2): 201-204.

Singh, K.K., Goswami, T.K., 1996. Physical Properties of Cumin Seed. Journal of Agricultural Engineering Research, 64 (2): 93-98.

Wani, I.A., Hamid, H., Hamdani, A.M., Gani, A., Ashwar, B.A., 2017. Physico-chemical, rheological and antioxidant properties of sweet chestnut (*Castanea sativa* Mill.) as affected by pan and microwave roasting. Journal of Advanced Research, 8 (4): 399-405.