Biological Forum – An International Journal **8**(1): 67-74(2016)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Investigating the viscoelastic behavior of chickpea grain during process of Nokhodchi (roasted chickpea) production

Reza Fellegari*, Hamid Reza Ghassemzade*, Mohammad Moghdam Vahed** and Ebrahim Ahmadi***
**Department of Biosystems Engineering, Faculty of Agriculture, University of Tabriz, IRAN*
***Department of Plant Breeding and Biotechnology, Faculty of Agriculture, University of Tabriz, IRAN*
****Department of Biosystems Engineering, Faculty of Agriculture, Bu-Ali Sina University, IRAN*

(Corresponding author: Reza Fellegari)
(Received 08 December, 2015, Accepted 19 January, 2016)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Roasted chickpea is one of the most important products of the city of Mamaghan, located in East of Azarbaijan province, and it has a significant role in this province employment. The roasted chickpea's production process includes the preparation of raw chickpeas, first heat treatment (FHT), second heat treatment (SHT), moisture treatment (MT) and roasted chickpea's preparation. Now the roasted chickpea's production is done manually. The mechanization process of producing this valuable product requires the investigation of viscoelastic behavior during the production phases. In this study, the chickpea's time-dependent mechanical behavior was investigated based on rheological theories. The results showed that the three-term model of Maxwell is the best choice to describe the viscoelastic behavior. For doing experiments, the texture analyzer device available in Bu-Ali Sina University was used. The results showed that from raw chickpea stage to FHT stage, modulus and stress relaxation time increased and from FHT to SHT stage, modulus and stress relaxation time decreased. Also, the comparison of the moisture treatment (MT) stage to the roasted chickpea's preparation phase shows that the modulus and stress relaxation time are increasing.

Key words: stress relaxation, Maxell model, Mamghan, roasted chickpeas.

INTRODUCTION

The chickpea is one of the most important sources of protein in the diet, and also it is a good alternative to animal sources. Also, the chickpea caused Nitrogen fixation in soil sources. Chickpea is usually used complete or dehulled, after cooking or after other technological undertakings (Morad *et al.* 2015). In the world, the process of cooking and processing chickpea is mainly being done in Iran, Turkey and India. And in Iran, this industry is unique to East of Azerbaijan province, to the city Mamghan. In Mamghan city, the chickpea processing is done manually and in a traditional way. During the processing of chickpeas, Viscoelastic properties of the chickpeas will change noticeably. On the other hand processing stages mechanization, especially skin processing steps, requires being familiar with the physical and mechanical properties of chickpea processing stage. One of the most important characteristic of the viscoelastic material in agricultural products is stress break, in a fixed initial stress deformation, stress will reduce permanently that is called stress break or stress reduction. Mohsenin (1986) & Koksel *et al.* (1998) compared the structures of raw and roasted chickpeas. This is a comparison based on the changes of structure and color of chickpeas, during roasting processes. Chickpea's structural changes were investigated by the scanning electron microscope (SEM).

The results showed that raw chickpea has a dense structure and after roasting processes, the chickpea's structure changed completely. Also, roasted chickpea compared to raw chickpea, has a dim color. Afkari Sayyah and Minaei (1383) studied the mechanical and rheological characteristics of wheat for qualitative classifications. Data analysis revealed that the humidity factor had a significant effect on the viscoelastic properties of wheat grain. In another study; using a general model of Maxwell, the stress relaxation behavior of soybeans was studied. In this experiment, the temperature and moisture factors were identified as affecting factors on the mechanical behavior of grain (Heram *et al*, 1979). Khazayi and Mann (2005) studied the stress relaxation of chickpea grain. Their aim was to study the effect of some loadings on chickpea based on it's moisture content. In this study, the Maxwell's three term model was used in parallel way. The results showed a negative correlation between the module and the humidity. Bargl and colleagues (1994) examined the characteristics of lentil stress relaxation due to the influence of moisture content in the modulus of elasticity and stress time.

For describing the stress relaxation behavior of lentil, Maxwell model was used. The purpose of the study was to determine the number of model's term. The results showed that the best model for testing the data is the three-term model. And also, by increasing the moisture content, the modulus and the stress time decreased. According to the investigation of existing literature, during the chickpea processing for producing roasted chickpea, there has not been any survey to examine the viscoelastic behavior of chickpea. The aim of this study was to compare the amount of modulus elasticity and describe the viscoelastic behavior of chickpea, during the chickpea processing.

MATERIALS AND METHODS

A. Theoretical Basis of the Model

Size and speed of reducing stress depend on the structure and the size of the deformation. Reducing stress is usually fixed. The behavior of an elastic material is like a spring behavior, while the behavior of a liquid is fitted with Dashpot measure. So, for investigating the behavior of a viscoelastic material, we can consider a device made of a combination of spring and Dashpot, and the resulting mechanical collection model is called Rheological model. This model is useful to show the chickpea's response under stress relaxation position. Maxwell model includes a series of combined spring and dashpot, and the general Maxwell model is one of the most important rheological model for describing the behavior of biological materials. This model includes some Maxwell models and a spring that are connected to each other in a parallel way.

The general Maxwell model includes Maxwell components and one spring component

The first equation shows the rheological equation of Maxwell model and one spring component (Mohsenin, 1986; Maghsodi *et al.* 1387; Liks, 1999).

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

In this equation, $E(t)$ functions the decreased elasticity modulus during the time, and t shows the break time. E_i and $_i\tau$ are model coefficients. A Dashtop coefficient is calculated by the following equation: $\eta_i = \frac{E_i}{\tau_i}$. The stress relaxation curve functions as the viscoelastic characteristics of chickpeas (Bargel 1995; Maro *et al.* 1966). After starting the proper loading speed, when there is a fixed strain in the sample, stop loading, and try to write down the stress changes towards the passage of time. When the value of stress reaches to 8.36%, the overall stress relaxation comes. For analyzing data, the stress data are drawn logarithmic and based on time, and the equation 14 fitted on the matching chart and the stress average time is being used (Mohsenin, 1986). The model's parameter depend on the manufacturer of the device and the model sterm are computerized that is calibrated in the device. The general equations in rheology model previously derived by researchers and by applying boundary conditions, practical equations are defined applied to particular conditions.

The preparation of samples

According to the study, sampling of all processing stages of roasted chickpea was done. These stages are shown in figure 2. The capacity of the roasted chickpeas processing equipment was about 50kg. At first raw chickpeas were cleaned. The optimal size of chickpeas for the production of roasted chickpea is about 8 to 9 mm. In the next step, Two-stage thermal treatment is done for affecting the structure of the chickpea and subtracting the adhesion of the skin and the flesh. Then, the chickpea is placed under 10% moisture, and for moisturizing chickpea, spraying method is used. At the last stage, after 16 to 24 hours relaxation, chickpea is placed in the peeling and roasting machine. And finally, the output of these stages would be placed on the market as a roasted chickpea. Random sampling was done at the end of each stage and the moisture content of each sample was measured by AOAC method (AOAC, 1980).

Comfort stress test. In tests determining the chickpea's comfort behavior, the effect of processing (cleaning, raw chickpeas, the first heat treatment, the second heat

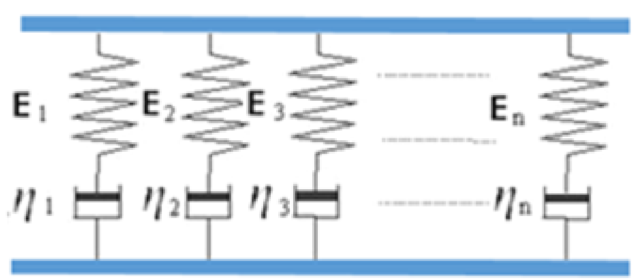

Fig. 1. Maxwell general model included n-term.

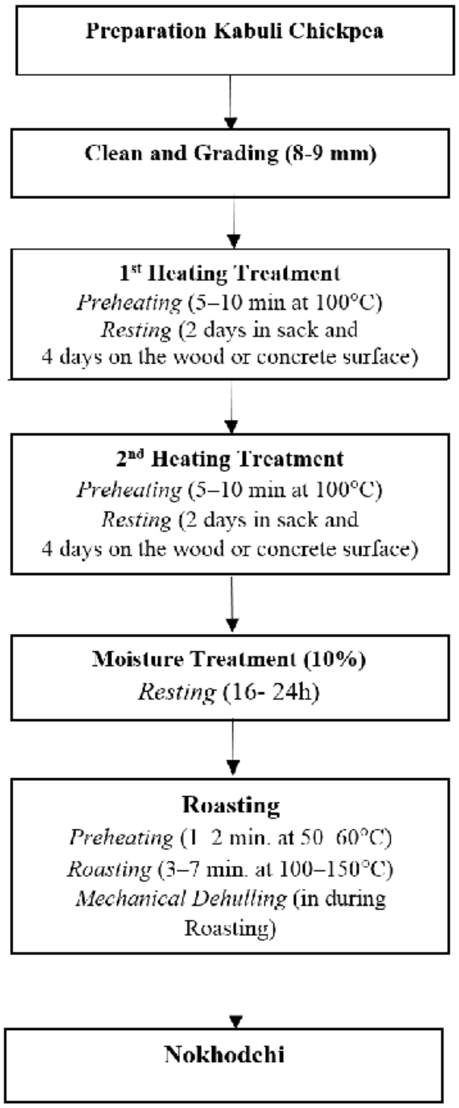

Fig. 2. The stages of chickpea's processing.

treatment, the moisture content of the roasting beans) was analyzed. Tests were conducted carefully by analyzer. In all tests, the loading rate was constant and equal to1 mm/s. This rate was chosen to provide the quasi-static loading conditions (Khazaei and Man, 2005; Bargol *et al.* 1994; Afkari *et al.* 2004). For this test, the grain is placed between two parallel plates which were compressed by their side (Fig. 3). With initial experiments and also based on literature, the level of initial strain (deformation of the grain in order to load compared to the original size) was determined at 10%. After the start of loading, when the strain of interest (10%) of the sample occurs and the loading process stopped; force changes over time (300 seconds) stored in the memory.

Then, the amount of stress was calculated by dividing forces by the chickpea's area of contact with the probe. In the next step of dividing the stress data by the constant strain, modulus chart was drawn. The number of model's elements was chosen according to the R^2, RMSE, 5% MRD≤ values. Eqnation shows how to calculate MRD (Almashat & Zorik, 1993; Sandoval *et al.* 2009).

Fig. 3. Chickpea's conditions for Stress relaxation test.

RESULTS AND DISCUSSION

To describe the chickpea's stress behavior at different stages of processing, general Maxwell model, which was presented, was used. Analysis of module diagrams, for a long time, showed that the amount of remaining spring element (E_∞) in the Maxwell model is close to zero and it is better no to be applied in model (Bargol, 1994). So one, two and three-term Maxwell, for this experiment, is made as follows:

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

MRD, R^2 and RMSE levels for models Maxwell one, two and three-components Maxwell model, for different stages of processing data, are shown in Table 1. Viscoelastic coefficient values of Maxwell models in processing steps (raw chickpeas, first heat treatment, second heat treatment, water treatment and roasted chickpeas) have also been shown. R^2 values in Maxwell's three-term model for raw chickpeas, the first heat treatment, second heat treatment, and roasted chickpea were 0.9891, 0.9923, 0.9926, 0.9905and 0.9940. In Maxwell's two-term model. The R^2 value ranges between 0.9249 and 0.9740 and in one-component model was between 0.5103 and 0.7260. The value of MRD in Maxwell's three-term model for raw chickpeas, the first heat treatment, the second heat treatment and the roasted chickpea were 2.01, 2.41, 1.10, 4.89 and 2.70 percent. MRD value in Maxwell's

Table 1: Comparing R^2, 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	19.20	0.6379	0.4958	5.50	0.9622	0.1434	2.01	0.9891	0.0859
FHD	12.71	0.6858	0.2982	3.99	0.9718	0.0893	2.41	0.9923	0.0467
SHD	13.49	0.6401	0.3296	3.03	0.9740	0.0886	1.10	0.9926	0.0472
MT	56.13	0.5103	0.2155	27.48	0.9249	0.0844	4.89	0.9905	0.0310
Roasted Chickpea	15.70	0.7260	0.2010	7.60	0.9710	0.0900	2.70	0.9940	0.0040

two-term model ranges between 3.30 and 27.48 and in one-term model, it was between 12.71 to 56.13.On the other hand, according to Table 1, by increasing the Maxwell's model terms, RMSE values will reduce. So by comparing MRD, R^2 and RMSE, three-component Maxwell model was chosen as the best model for describe the rheological behavior of chickpea processing. Maxwell three-component model for roasted chickpeas can be expressed as follows:

$$E(t) = 1.92 \exp\left(-\frac{t}{5998}\right) + 0.17 \exp\left(-\frac{t}{20.41}\right) + 0.16\, exp(-1.257)$$

Graphs of relaxation modulus versus time at different stages of processing chickpeas are shown in Fig. 5, 6, 7, 8 and 9. It is clear that the three-component model in the best choice for experimental data. Table 1 compares the MRD, RMSE and R^2, one term, two-term and three-term Maxwell in roasted chickpeas processing stages.

Given that the modulus elasticity coefficient values (E1) and relaxation time (τ_1) of the first part of the three-term Maxwell model had the greatest impact and contribution in the model were used for data analysis. Evaluating the value of modulus of elasticity models in various conditions shows that from the processing of the raw chickpeas to the first heat treatment, its value increases and from the first heat treatment to the second heat treatment, its value decrease. Also, the moisture contents of the chickpea's treatments from the raw chickpea stage to the second heat treatment stage, due to heat in the furnace, decrease (Fig. 2). The results of studies investigate the modulus of elasticity in relaxation condition in products such as wheat, chickpeas and beans in the different strands, represents an increase in modulus number with moisture reduction (Shelf & Mohsenin, 1967; Khazaei *et al.* 2005).Changing process of Modulus from the raw chickpea stage to the first heat treatment process showed an increasing consistent with the studies cited. But the remarkable point was chickpea's restructuring, due to the increase in the plastic properties and decrease in stress modulus in a second heat treatment. In fact, the impact of chickpea's restructuring on module, in the second heat treatment, was greater than the effect of reducing the moisture content and, elastic modulus decreased. In moisture treatment stage, by increasing the amount of chickpea's moisture, there was a sharp drop in modulus of elasticity (Fig. 4).

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

Processing phase	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	20.78	2584.12	20.49	3725.34	3.63	7.78	21.19	4499.19	1.61	18.98	1.59	2.53
FHD	22.70	3911.00	20.05	5856.00	4.81	10.05	22.22	7222.00	1.86	23.13	2.85	2.90
SHD	20.12	3726.00	19.85	5791.00	2.47	11.01	19.87	7005.00	1.55	21.28	1.60	2.68
MT	1.55	409.60	1.29	695.30	1.08	11.07	1.24	816.60	1.02	2.01	0.75	1.23
Roasted Chickpea	1.96	3570.00	1.94	4795.00	1.21	12.23	1.92	5998.00	1.17	20.41	0.87	1.25

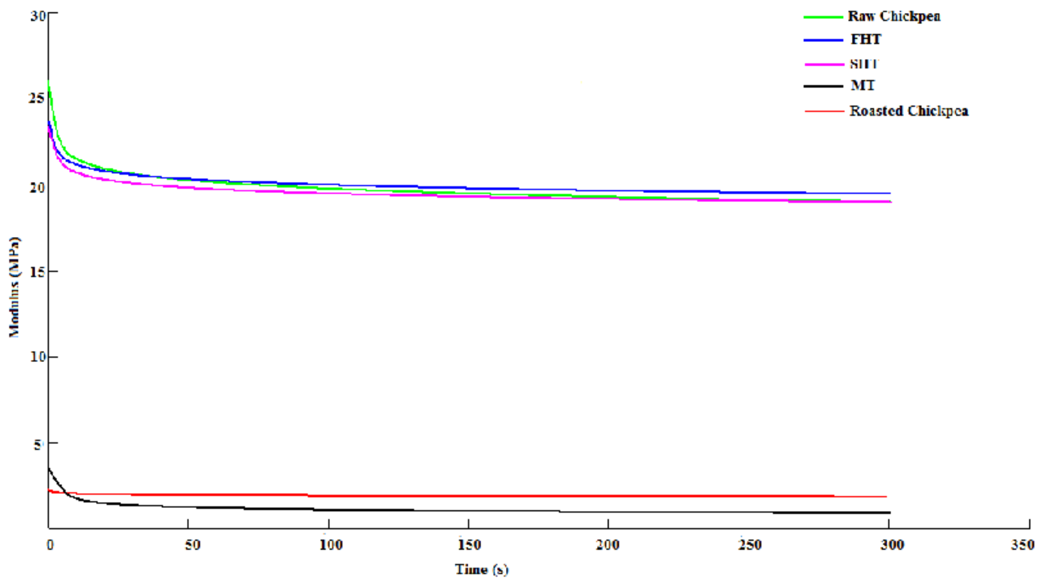

Fig. 4. Comparing module- time diagrams for different processing phase.

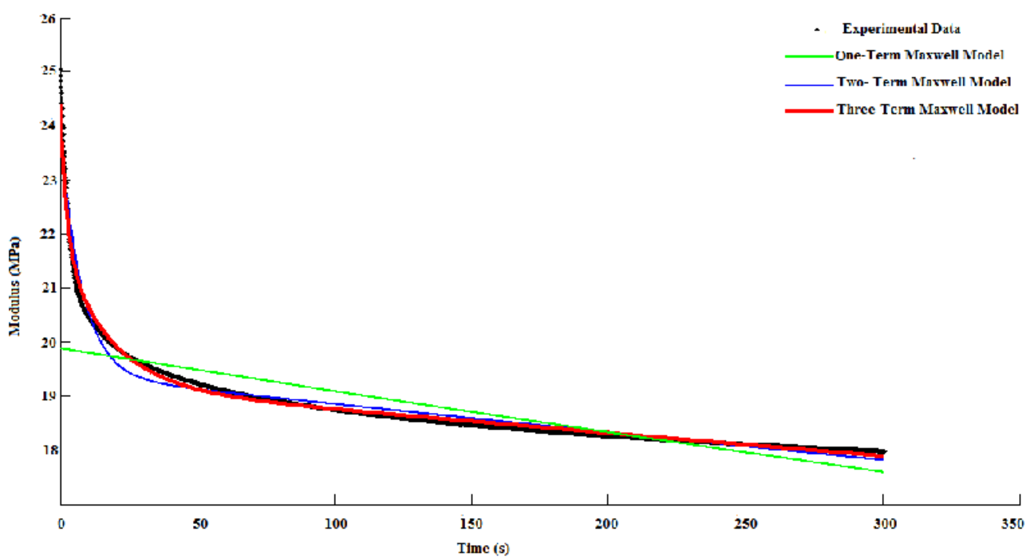

Fig. 5. Row Chickpea stress relaxation behavior by fitting one, two and three term Maxwell models to experimental data.

At this stage, the impact of moisture increase in the module, without heat treatment, was consistent with the studies cited. Also, at the roasted beans phase, due to heat treatment and humidity decrease, the modulus of elasticity, compared to the moisture treatment phase, increased (Fig. 4). The stress relaxation time of the raw chickpea phase to the first heat treatment phase increased from 4499 to 7222 seconds, while from the first heat treatment phase to the second heat treatment, this amount was reduced to 7005 second. The Increasing amount of stress relaxation over time was a sign of elasticity property increase, and its decrease shows the viscose property increase. On the other hand from the second heat treatment phase to the moisture content phase, by increasing the amount of moisture, the chickpea's viscose properties increased and thereby the amount of stress relaxation time reduced to 816 seconds. In The roasted beans phase, because of the thermal treatment, the chickpea's moisture reduced and the reduction of moisture caused the stress relaxation time increased to 5998 second.

The results showed that the increase and decrease of stress relaxation time is like modulus. Comparing the time of the roasted chickpea's modulus and the second heat treatment phase, there was a sharp drop in the roasted chickpea's module (from 19.87 to 1.92), which represents a structural change in the cellulose structure of chickpea. In fact, applying moisture and heat treatments, (browning) increased viscous properties of chickpea and reduced rigidity.

Applying the thermal and moisture treatments, during the process of roasted chickpea, lead to the formation of the roasted chickpea's structure for making it edible.

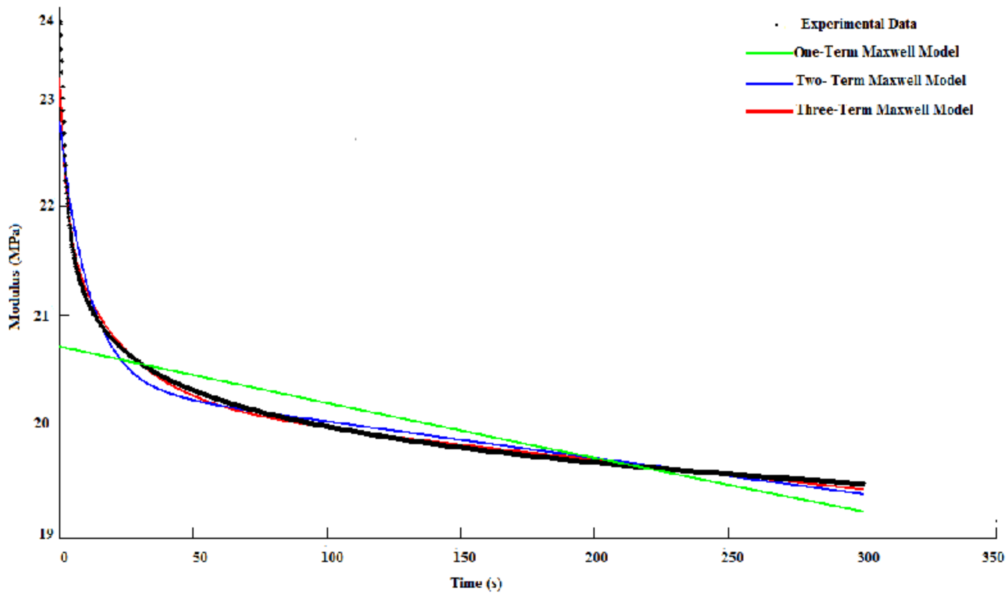

Fig. 6. FHT stress relaxation behavior by fitting one, two and three term Maxwell models to experimental data.

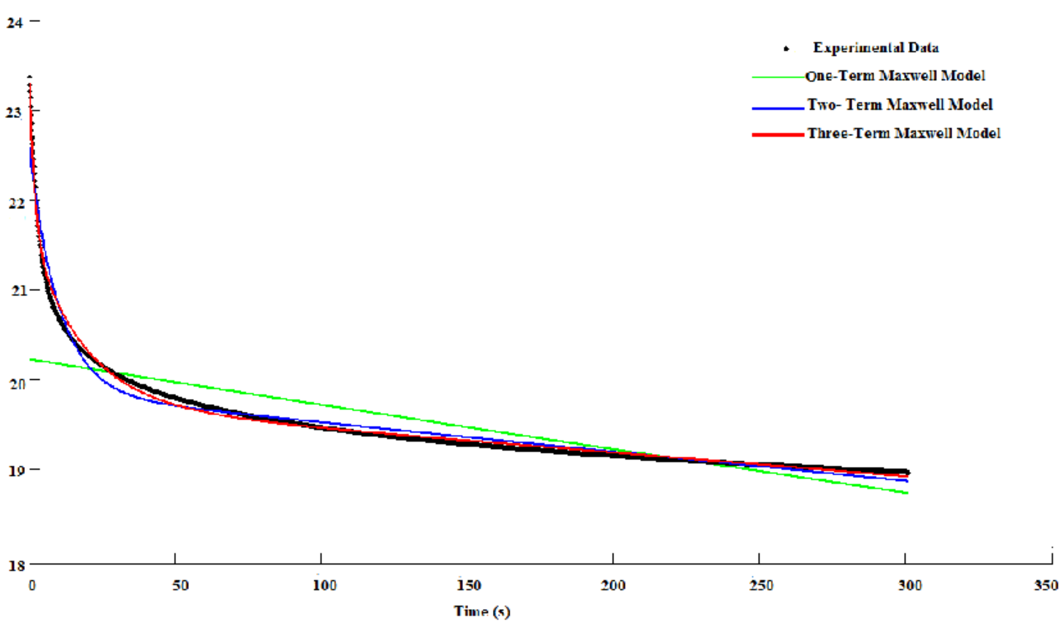

Fig. 7. SHT stress relaxation behavior by fitting one, two and three term Maxwell models to experimental data.

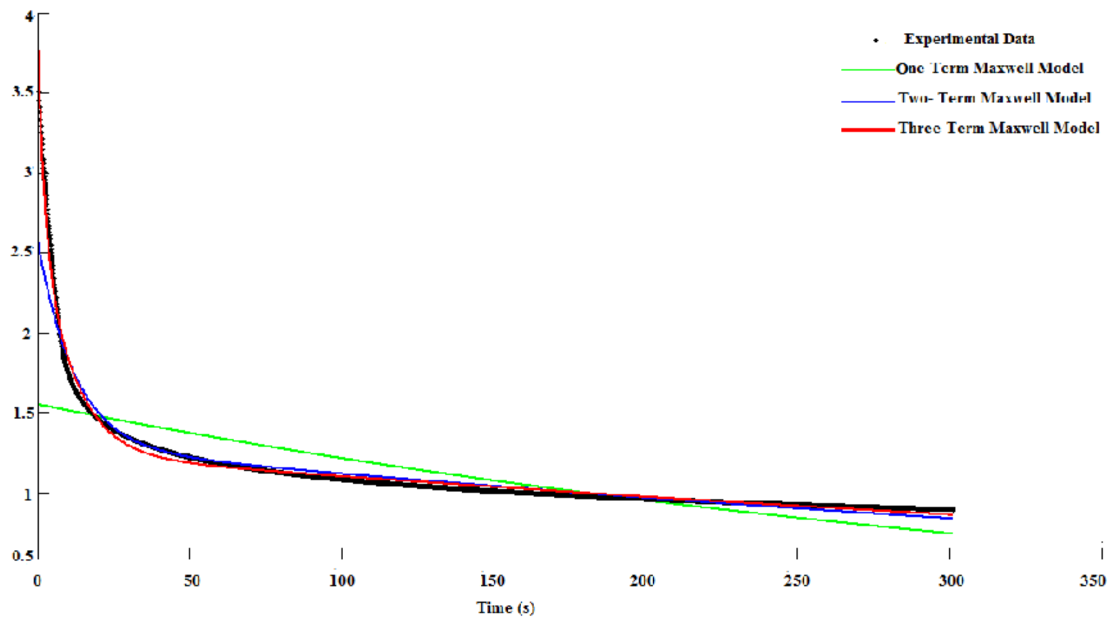

Fig. 8. MT stress relaxation behavior by fitting one, two and three term Maxwell models to experimental data.

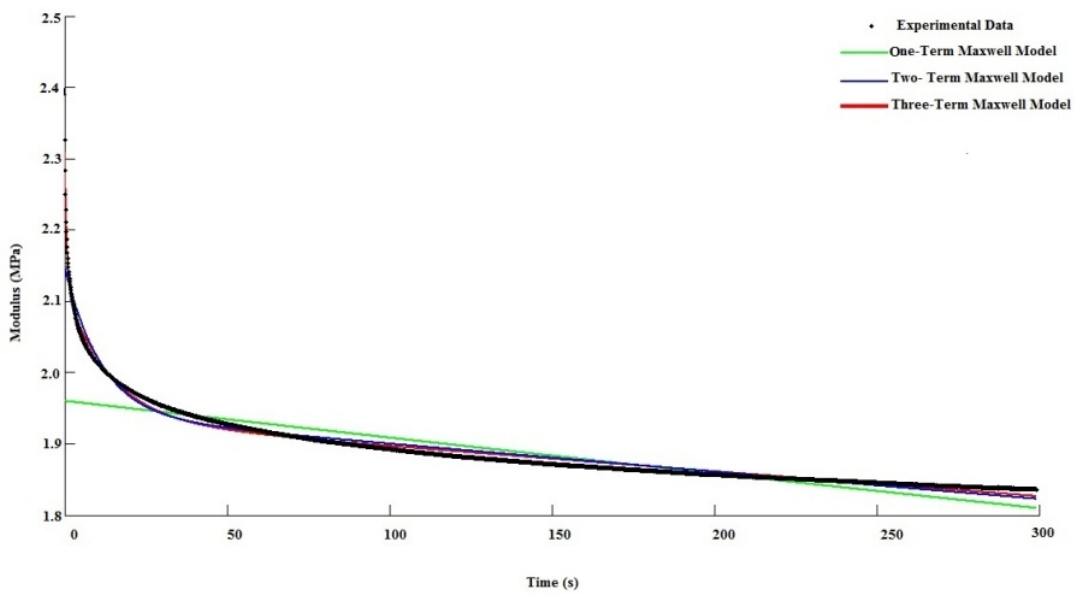

Fig. 9. Roasted chickpea stress relaxation behavior by fitting one, two and three term Maxwell models to experimental data.

REFERENCES

Al-Mashat, S.H.I. Zurit, C.A. (1993). Stress relaxation behavior of apple pomace and effect of temperature, pressing aid and compaction rate on juice yield. *J. Food Eng.*, **20**, 247-266.

Aneja, K.R. (2005). Experiment in Micro biology, Plant pathology and Biotechnology. New Age Publishers, pp. 69-115.

AOAC. (1980). Official Methods of Analysis. Association of Official Analytical Chemists, Washington, DC, USA.

Barglel, P. C. &Iiudayaraj, M. (1995). Mechanical strength and rheological behaviour of barley kernels. *International Journal of Food Science and Technology*, **30**, pp. 609-623.

Barglel, P. C., Iiudayaraj, J. M. & Marquis, B., (1994). Some mechanical properties and stress relaxation characteristics of lentils. *Canadian Agricultural Engineering*, **36**(4), pp. 247-254.

Bayer, E.A., Belaich, J.P. Shoham, Y. and Lamed R. (2004) The cellulosome :multienzyme machines for degradation of plants cell wall polysaccharide. *Annu Rev micribio 2004*; **58**: 521-554.

Herum, F. L., Mansah, J. K., Barre, J. H. and Majidzadeh, K. 1979. Viscoelastic behavior of soybeans due to temperature and moisture content. Transactions of the ASAE, pp. 1219-1224.

Khazaei, J. & Mann, D. D., 2005. Effects of moisture content and number of loadings on force relaxation behavior of chickpea kernels. *International Agrophysics*, Volume **19**, pp. 305-313.

Kluepfel, D., (1988). Screening of prokaryotes for cellulose and hemicellulose-degrading enzymes. *Methods enzymol*., **160**: 180-186.

Koksel, H., Sivri, D., Scanlon, M. G. & Bushuk, W. (1998). Comparison of physical properties of raw. *Food Research International*,**31**(9), pp. 659-665.

Lakes, R. S. (1999). Viscoelastic Solids. 1st edn.,Bocaraton, Florida. CRC Press, 476 p.

Leboffe, M.J. and Pierce, B.E. (2010). Microbiology Laboratory-Theory and Applications, 3rd Ed. Morton Publishing Company.

Mohsenin, N. N., (1986). Physical Properties of Plant. 2nd ed. New York: Gordon and Breach Science Publishers.

Morrow, C. T. & Mohsenin, N. N., (1966). Consideration of selected agricultural products as viscoelastic materials. *Journal of Food Science*, **31**(5), pp. 686-698.

Mrad, R., Rammouz, R. E., Maroun, R. G. & Louka, N., (2015). Effect of intensification of vaporization by decompression to the vacuum as a pretreatment for roasting Australian chickpea: multiple optimization by response surface methodology of chemical, textural and color parameters. *Journal of Food Quality*, **38**(2), pp. 139-152.

Paul, E.A. and F.E. clerk. (1989). Soil microbiology and biochemistry. Academic press, Inc., New York.

Sandoval, E.R., Quintero, A. F., Cuvelier, G. (2009). Stress relaxation of reconstituted cassava dough. *Food Science and Technology*, **42**, pp. 202-206.

Shelef, M., Mohsenin, N. N. 1967. Evaluation of the modulus of elasticity of wheat grains. *Cereal Chemical*, **44**, pp. 392-402.