*Soybean Research (Special Issue Number 2): 236-240: 2014*

# Effect of Different Roasting Temperature and Time on Mechanical Properties of Whole Soybeans

***RANJIT SINGH*[1*]*, RAHUL DEBBARMA*[*2]*, SANDEEP SINGH RANA*[3*]
*and KHURSHEED ALAM KHAN*[4**]*,
***Indian Institute of Crop Processing Technology, Thanjavur, India and***
*****Central Institute of Agricultural Engineering, Bhopal, India***
E mail: ranjit_mfe12@iicpt.edu.in

## ABSTRACT

*This study investigates the mechanical behaviour (hardness, toughness, rupture force) of roasted whole soybeans. The geometric mean diameter of whole soybeans was measured 5.82 ± 0.07 mm with 12 per cent moisture content (db). During the experiment, maintaining steeping time (0 and 30 min), processing temperature (140 °C, 160 °C, 180 °C and 200 °C) and roasting time (60, 120 and 180 sec) revealed that hardness, toughness and rupture force decreased as temperature and time of roasting increased. Minimum hardness was 102.51 N (30 mint, 180 °C and 120 sec), maximum hardness was 253.64 N (0 mint, 140 °C and 60 sec). Minimum toughness was 71.43 N-mm (30 mint, 180 °C and 120 sec), maximum toughness was 176.86 N-mm (0 mint, 140 °C and 60 sec). Minimum rupture force 27.34 N (30 mint, 200°C and 180 sec) and maximum rupture force 115.67 N (0 mint, 140 °C and 60 sec). The best temperature and time combination for crushing or breaking of roasted whole soybeans was found 30 minute steeping, 180 °C roasting temperature and 120 second roasting time. In some of the cases minimum hardness, toughness and rupture force are found at higher roasting temperature and roasting time, but soybeans are over roasted, there is a chance of reduction in quality parameters. This information are useful in the determination of size reduction, crushing, breaking or grinding of whole soybean and designing equipment for milling, especially for soybeans crusher or grinder machine who raise livestock.*

**Key words**: Hardness, roasting, rupture force, toughness, whole soybeans

Soybean [*Glycine max* (L.) Merrill] is a species of legume native to Eastern Asia. Among the legumes, the soybean is classified as an oilseed (Perkins, 1995). Nowadays it is used as multi-purpose crops and good source of protein and fat for human and animals all over the world. It contains 40 per cent protein and 20 per cent fat (Kulkarni, 1994). Generally soybeans are processed to be used as animal feed. One of the important processing of whole soybeans is roasting. Roasting improves flavour, texture and nutritive value of the grains and eliminates toxic effect or anti-nutritional effect of legumes (Liener, 1973). Roasted whole soybeans are an excellent source of rumen undegradable protein, but there could be variation in quality, which depends upon the roasting parameters. Roasting results in increase protein digestive value, but it varies according to temperature and time of roasting (Srivastav *et al.*, 1990). Biochemical composition of grains affects the grain hardness. Although, the effect of protein content on grain hardness is minor, it varies with crop varieties (Moss *et al.*, 1980 and Symes, 1965). Steeping time, processing temperature and roasting time dramatically

*[1,3]M Tech Student; [2]Research Scholar; [4]Research Associate*

affect the chemical and mechanical properties of roasted soybeans. Faldet *et al.* (1992) estimated (*in vitro*) that postruminal availability of lysine was maximized at roasting temperatures between 140 and 160 °C, given that soybeans were held at these temperatures for a minimum of 30 min with an additional 4.5 min for each 1°C below 160 °C. *In vivo* data are largely unavailable regarding the level of heating necessary to maximize both ruminal protein escape and small intestinal digestion. Reddy *et al.* (1993) demonstrated that optimum quality of roasted soybeans was achieved when the temperature was between 143 °C and 146 °C but they did not mention optimum roasting and steeping time. Nowadays, engineers are interested to design equipment for milling and size reduction of soybean like soybean crasher, grinder and oil extracting machine. There is a need to know the hardness, toughness and rupture force of roasted soybeans at particular time and temperature. Therefore, the objectives of this study were to investigate the mechanical behaviour (hardness, toughness and rupture force) of roasted whole soybeans and to find the optimum time and temperature combination for crushing or breaking of roasted whole soybeans.

.

**MATERIAL AND METHODS**

Soybeans were purchased from Thanjavur Super market, Tamil Nadu. The geometric mean diameter of whole soybeans was measured 5.82 ± 0.07 mm with the help of verniercaliper and initial moisture content of soybeans were determined by standard oven drying method at 105 ± 5°C for 24 h and was reported at 12 per cent (d.b). During the experiment, steeping time of 0 and 30 minute was maintained and after steeping soybeans were dried in hot air oven having temperature 55 ± 2 °C for 90 min, then roasting was done at four different temperatures (140, 160, 180 and 200 °C) at 30 second interval up to 180 sec. To determine the mechanical properties of soybean, a proprietary tension/compression testing machine (Instron Universal Testing Machine /SMT-5, SANTAM Company) equipped with a 500 kg compression load cell and integrator was used (Saiedirad *et al.*, 2008). The measurement accuracy was ± 0.001 N in force and 0.001 mm in deformation. The individual grain was loaded between two parallel plates of the machine and compressed along with thickness until rupture occurred as is denoted by a rupture point in the force–deformation curve. There was formation of shear band during compression. Thickness of develop shear band was 15 times bigger than mean diameter in case of mustard seed compression test (Horabik *et al.*, 2000). The rupture point is a point on the force–deformation curve at which the loaded specimen shows a visible or invisible failure in the form of breaks or cracks. This point is detected by a continuous decrease of the load in the force-deformation diagram. While the rupture point was detected, the loading was stopped. These tests were carried out at the loading rate of 5 mm per min for treatments (ASAE, 2006).

Grains having higher moisture content, rupture force on the grain will decrease, while rupture energy will increase (Tavakoli *et al.*, 2009). The mechanical behaviour of soybean grains were expressed in terms of rupture force and rupture energy required for initial rupture. Three replications were made for each test and 10 samples were used in each test. Energy absorbed by the sample at rupture was determined by calculating the area under the force–deformation curve from the following relationship (Braga *et al.*, 1999).

$E_a = F_r \times D/2$, where, = $E_a$ rupture energy; = $F_r$

rupture force; and = $D_r$ deformation at rupture point

The results obtained were subjected to analysis of variance (ANOVA) using SPSS 20 software.

## RESULTS AND DISCUSSION

The effect of roasting on mechanical properties of soybean grains was significant at 5 per cent probability level. Results obtained are discussed in detail below.

### Hardness

Grain hardness is known to get affected by size, direction of applied force, moisture content, chemical composition and heat treatment (Abdelrahaman and Hoseney, 1984). Energy consumption, fineness of finished products and sieving behaviour of grains depend on grain hardness (Tran *et al.*, 1981). It was seen that hardness decrease with increase in roasting temperature and time of roasting [Fig 1(a) and 1(b)]. Minimum hardness was 84.65 N keeping 0 minute steeping time, 200 °C roasting temperature and 180 second roasting time (in case of without steeping), but after 30 minute steeping time; the hardness value is 71.65 N under the same condition.

### Toughness

In case of toughness, material is known to absorb energy and plastically deform without any fracture. Toughness value of soybeans deceases with increase in roasting temperature and steeping time. Least toughness value found 60.34 N at 200 °C, 180 sec roasting time and 0 minute steeping process, but after 30 minute of steeping process toughness value was 45.07 under same condition [Fig. 2(a) and 2(b)].

### Rupture force

Moisture content of roasted soybeans decreased with increase in both roasting temperature and time. At the lower moisture levels, the rupture energy was low and *vice versa*. Average rupture force decreased with increase in roasting temperature. Lowest rupture force was obtain in case of 30 minute steeping time, 200 °C and 180 second roasting temperature its value is 27.34 N [Fig. 3(a) and 3(b)].

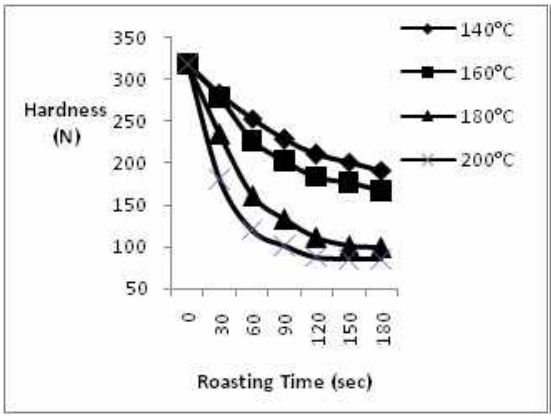


**Fig. 1(a). Effect of roasting without steeping**

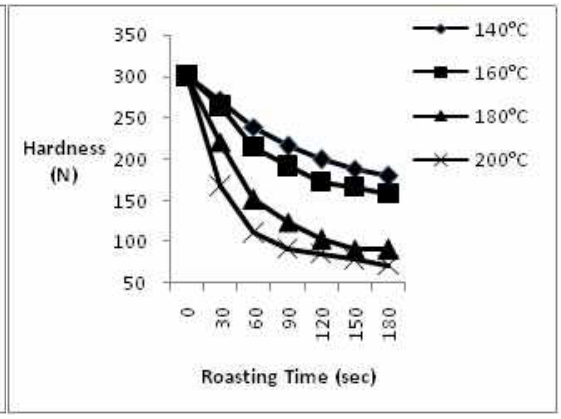


**Fig. 1(a). Effect of roasting, 30 min steeping**

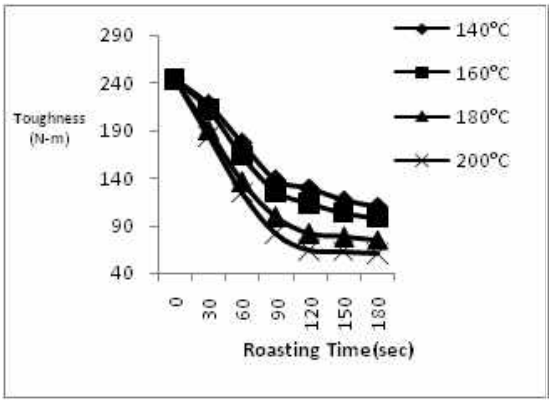


Fig. 2(a). Effect of roasting without steeping

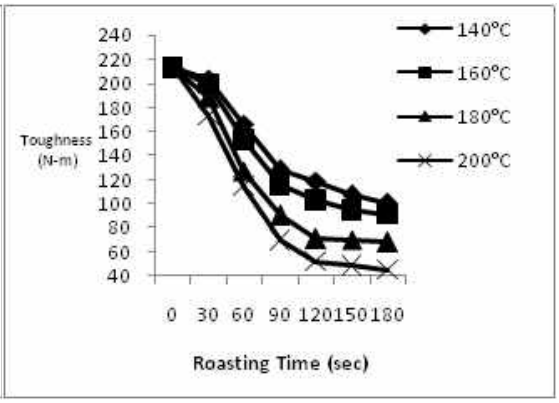


Fig. 2(b). Effect of roasting, 30 min steeping

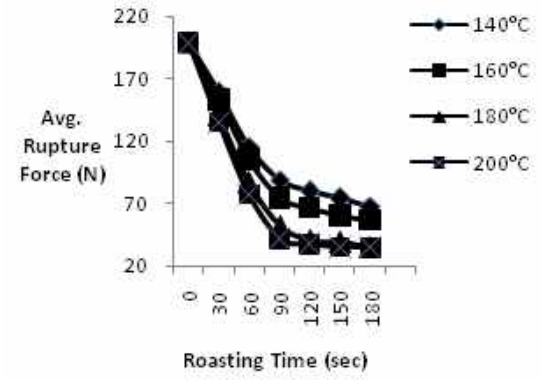


Fig. 3(a). Effect of roasting without steeping

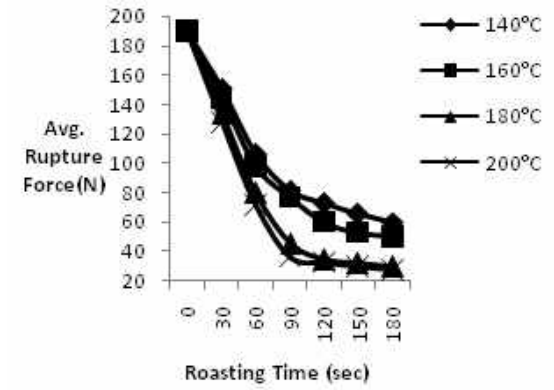


Fig. 3(b). Effect of roasting, 30 min steeping

The effect of temperature and roasting time on soybeans hardness, toughness and average rupture force is presented in non-linear polynomial regression equation (Table 1).

**Table1. Analysis of variance for mechanical properties of roasted soybeans**

| Characteristics | Source of variation | df | SS | MS | f-ratio |
|---|---|---|---|---|---|
| Hardness | Te mperature | 2 | 48603 | 24301.5 | 129.51* |
| | Time | 2 | 28859 | 14429.5 | 79.78* |
| Toughness | Temperature | 2 | 80762 | 40381 | 61.45* |
| | Time | 2 | 41260.3 | 20630.15 | 30.65* |
| Average rupture | Temperature | 2 | 10590.2 | 5295.1 | 97.89* |
| Force | Time | 2 | 7896.6 | 3948.3 | 59.87* |

** Means significant at 5% significance level*

$R^2$ value for hardness, toughness and average rupture force is 0.89, 0.87 and 0.84, respectively.

Roasting of soybeans at different temperature, time and steeping process affected the mechanical properties of soybeans. It was found that steeping of soybean gives lower hardness, toughness and rupture force than without steeping soybeans. As per fig. 1, fig. 2 and fig. 3, the minimum value of hardness, toughness and rupture force is 30 minute steeping time, 200°C roasting temperature and 180 second, but in this case minimum hardness, toughness and rupture force were found at higher roasting temperature and roasting time, due to soybeans are over roasted and there is a chance of reduction in quality parameters.

This study suggested that the best temperature and time combination for crushing or breaking of roasted whole soybeans were 30 minute steeping, 180°C roasting temperature and 120 second roasting time. This information is going to be handy for engineers to design equipments (crasher, grinder and for oil extraction) for milling and size reduction for soybean.

**REFERENCES**


Abdelrahman A A and Hoseney R C. 1984. Basis for hardness in pearl millet, grain sorghum, and corn. *Cereal Chemistry* **61**(3): 232-5.

ASAE. 2006. Compression test of food materials of convex shape. S368.4, 609-16.

Braga G C, Couto S M, Hara T and Neto J T P A. 1999. Mechanical behaviour of macadamia nut under compression loading. *Journal of Agricultural Engineering Research* **72:** 239–45.

Faldet M A, Satter L D and Broderick G A. 1992. Determining optimal heat treatment of soybeans by measuring available lysine chemically and biologically with rats to maximize protein utilization by ruminants. *Journal of Nutrition* **122**: 151.

Horabik J, Lukaszuk J and Grochowicz M. 2000. Formation of shearband in a granular material during triaxial compression test. *International Agrophysics* **14:** 273-8.

Kulkarni S D. 1994. Roasted soybeans in cookies: influence on product quality. *Journal of Food Science and Technology* **34:** 503-5.

Liener I E. 1973. Toxic factor associated with legume proteins. *Indian Journal of Nutrition and Dietetics* **10:** 303-22.

Perkins E. 1995. Composition of soybeans and soybean products. *Practical Handbook of Soybean Processing and Utilization*, Erickson E R (Ed), AOCS Press, Champaign, IL.

Moss R, Stenvert N L, Kingswood K and Pointing G. 1980. The relationship between wheat microstructure and flour milling. *Scanning Electron Microscope* **3:** 613.

Reddy P V, Morrill J L and Bates L S. 1993. Effect of roasting temperatureson soybean utilization by young dairy calves. *Journal of Dairy Science* **76:** 1387-93.

Saiedirad M H, Tabatabaeefar A, Borghei A, Mirsalehi M, Badii F and Varnamkhasti M G. 2008. Effects of moisture content, seed size, loading rate and seed orientation on force and energy required for fracturing cumin seed under quasi-static loading. *Journal of Food Engineering* **86**(4): 565-72.

Srivastav P P, Das H and Prasad S. 1990. Effect of roasting process variables on *in-vitro* protein digestibility of Bengalgram, maize and soybean. *Food Chemistry* **35**(1): 31-7.

Symes K J. 1965. The inheritance of grain hardness in wheat as measured by the particle size index. *Australian Journal of Agricultural Research* **16:** 113.

Tavakoli H, Mohtasebi S S, Rajabipour A and Tavakoli M. 2009. Effects of moisture content, loading rate, and grain orientation on fracture resistance of barley grain. *Research in Agricultural Engineering* **55**(3)**:** 85-93.

Tran T L, Deman J M and Rasper V F. 1981. Measurement of corn kernel hardness. *Canadian Institute of Food Science and Technology Journal* **14**(1): 42-8.