Madras Agric. J., 101 (4-6): 189-192, June 2014
https://doi.org/10.29321/MAJ.10.001179

# Fracture Resistance Behavior of Sunflower (var. Co 2) Seed and Kernel Under Compression Loading

**M.R. Manikantan[1*], T. Arul Selvam[2], Tarsem Chand[2], Rajiv Sharma[1], Sajeev Rattan Sharma[2] and M. Balakrishnan [3]**
[1]Central Institute of Post Harvest Engineering and Technology, Ludhiana, Punjab.
[2]Punjab Agricultural University, Ludhiana, Punjab.
[3]Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu.

**The objective of this study was to investigate the effect of moisture content on force and energy required for fracturing the sunflower (var. CO 2) seed and its kernel under compression loading. Initial Cracking Force (ICF), Mean Rupture Force (MRF) and Rupture Energy (RE) were studied with four different moisture levels (6 – 18%, d.b.). The obtained results showed that the initial cracking force and mean rupture force decreased linearly with increase in moisture content for both sunflower seed and kernel. However, the rupture energy was found to be increasing linearly for seed and kernel with moisture content. The values of all the studied attributes were higher for seed than kernel at all moisture levels.**

**Key words:** Moisture content, Sunflower var.CO 2, Initial cracking force, Rupture energy

Sunflower (*Helianthus annuus* L.) seed is considered to be an important oilseed crop due it's highly nutrition and oil composition. Sunflower oil represents up to 80% of its economic value (Evon *et al*., 2007). Like most oilseeds, sunflower has a potential utility for many industries. Different products can be obtained from crude oil, cake, hulls or refined oil, including manufacturing of margarine, paints, soaps, and cosmetics (Bamgboye and Adejumo, 2007). Its use as bio-diesel or as vegetable-oil based fuel for many vehicles, including farming equipment is feasible (Figueiredo *et al.,* 2011). The hybrid var. CO 2 sunflower was developed by Tamil Nadu Agricultural University, India and released in 1986. The crop can be grown over all seasons because of its photo- and thermo-insensitive nature and adaptability to all types of soil. Hence, this hybrid is widely cultivated in Tamil Nadu (Agritech, TNAU 2013). Sunflower oil is mostly obtained by mechanical expression from sunflower seeds, the process mainly consists of flaking and crushing is related to the external forces on each seed between the crushing surfaces. Therefore, a study of the relationship between the forces on a single sunflower seed and kernel is needed for a better understanding of oil expelling.

Many researchers have studied the fracture characteristics of various agricultural materials such as corn seed (Babic *et al.,* 2013), soybean (Bargale *et al.,* 1999), white seasame seed (Darvishi, 2012), pomegranate seed (Kingsly *et al.,* 2006) and sunflower seed (Gupta and Das, 2000; Khodabakhshian *et al.,* 2010; Gupta and Manikantan, 2006). Kang *et al.* (1995) reported that mean values of bio-yield strain and energy to bio-yield of wheat decreased as the moisture content increased at a loading rate of 1 to 250 mm min $^{-1}$. Owolarafe *et al.* (2005) studied the average cracking force and average pressure required for cracking of fresh palm fruit are 2301 N and 5.79 N mm$^{-2}$, respectively. Baumler *et al.* (2006) studied the compression behavior of safflower seed under quasi-static compressive loading at six level of moisture content varied from 3.7 to 15.6 % d.b. The samples were tested in horizontal and vertical orientations. It was observed that the force required for the hull rupture decreases as the moisture content increased, and it attained a minimum value at 11% (d.b.). The energy absorbed at rupture per unit volume of seeds for the horizontal position was always higher than vertical. Vursavus and Özgüven (2005) investigated the mechanical properties of pine nuts under compressive load at five moisture contents; the parameters studied were rupture force, deformation at rupture point, power requirement, and firmness. A compression plate at 8 mm/min speed was used acting on the two main axes of the product. Significant relationships between moisture and mechanical parameters were observed.

There is a general scarcity of published studies discussing fracture characteristics of sunflower seeds. A sound knowledge of var. CO 2 sunflower seed properties is required in the process of designing equipment for dehulling and oil expression. The objectives of this study were to investigate force and energy required for fracturing the sunflower seed and kernel with different moisture levels. The resulting data will benefit engineering efforts, and it will provide valuable inputs to new research pursuits.

## Materials and Methods

The authenticated sunflower seed hybrid var. CO 2 used in this research was acquired from Dept. of Plant Breeding and Genetics, Tamil Nadu Agricultural

[1]*Corresponding author email: maniciphet@gmail.com

University, Coimbatore, India. At the first, seeds were cleaned and graded in cleaner cum grader (CIAE, Bhopal) using 3 × 20 mm sieve to remove foreign matter, broken and immature seeds. To obtain whole kernels, seeds were dehulled using impact type sunflower dehuller (CIPHET, Ludhiana, India). The initial moisture content of the seed and kernel was determined by standard hot air oven method with the temperature settings of 130±1 °C for three hours (ASAE, 1999). The initial average moisture contents of the seed and kernel were found to be 6.11% and 5.74% (d.b.), respectively. The experimental moisture of the samples (6, 10, 14, and 18%, d.b.) was chosen according to the prevailing processing practices and obtained with either adding or removing distilled water using the procedure described by Singh and Goswami (1996).

The conditioned samples were sealed in low density polythene bags of 90 µm thickness and kept in refrigerator at 4 °C for one week for uniform distribution of moisture throughout the sample. Before starting the actual experiment, required quantity of sample was taken out from the refrigerator and allowed to equilibrate at room temperature for two hours (Singh and Goswami, 1996).

Fracture characteristics such as initial cracking force, mean rupture force and rupture energy were performed with Texture Analyzer (TA-HDi., Stable micro systems). The conditioned samples were visually inspected and randomly selected prior to testing, and those with visible immature seeds were discarded. Each individual seed or kernel was kept in natural rest position (Fig. 1) under the test probe and it was compressed at the pre-set condition until rupture occurred as is denoted by a bio–yield point (Sukumaran and Singh, 1989). The condition-set up in the texture analyzer for measuring compression test were: Pre-test speed, 1.0 mm $s^{-1}$; Test speed, 2 mm $s^{-1}$; Post-test speed, 5 mm $s^{-1}$; Test distance, 5 mm; Trigger type, Auto; Trigger force, 0.10 N; Load cell, 50 kg; Stainless steel cylinder probe, 5 mm diameter. The graph was drawn between the force resisted by the test material and time. From the graph, the initial peak position was considered as initial cracking of the test material and the force related to this initial peak position was considered as initial cracking force. The mean force experienced by the test material from zero to the test distance is considered as mean rupture force and the area under this curve is known as rupture energy.

The experiments were conducted with three replications for each moisture level and the mean values are reported. The effect of moisture content on force and energy required for fracturing both sunflower seed and kernel was investigated using analysis of variance (ANOVA) at 5% significance level with the help of SPSS 20.0 software.

## Results and Discussion

### *Initial cracking force*

The variation of initial cracking force of sunflower seed and kernel with standard error at 5% significance at different moisture contents are given in Fig. 2. The force required to initiate rupture of sunflower seed as well as kernel decreased as the moisture content increased from 6% to 18% d.b. The mean initial cracking force of sunflower seed and kernel ranged from 52.15 – 48.93 N and 25.40 – 16.11 N respectively. This may be due to the fact that at higher moisture content, the seed became softer and required less force (Saiedirad *et al.,* 2008). The trend of decreasing initial cracking force at higher moisture content might be also due to a gradual change in the integrity of the cellular matrix (Khodabakhshain *et al.,* 2010). Similar trends were also observed by Khodabakhshian and Shakeri (2012) for safflower, Gupta and Das (2000) for 'morden' variety of sunflower and Darvishi (2012) for white sesame seed. The effect of moisture and variety on initial cracking force for sunflower seed and kernel was also studied using ANOVA shown in Table 1 and 2, respectively. From the table it can be observed that, moisture content significantly influenced the initial cracking force ($p<0.05$) for both seed and kernel. The regression equations and their respective coefficients of determination ($R^2$) for the measured initial cracking force of seed and kernel as a function of moisture content are presented in Equations 1 and 2. As the

**Table 1. Analysis of variance for sunflower seed to study the significance level for variation in fracture characteristics with moisture content**

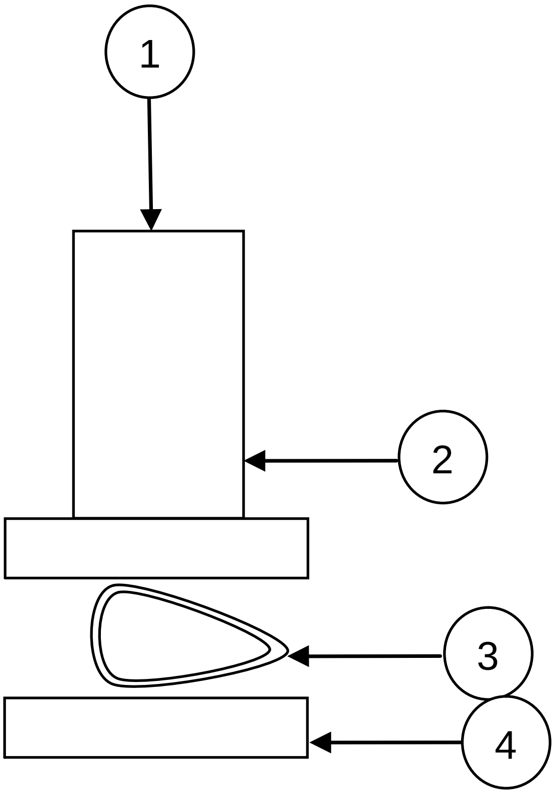
| Parameters | Source | Sum of squares | df | Mean square | $F_{Calculated}$ |
|---|---|---|---|---|---|
| ICF (N) | Between Groups | 18.22 | 3 | 6.07 | 8.27* |
| | Within Groups | 5.87 | 8 | 0.73 | |
| | Total | 24.09 | 11 | | |
| MRF (N) | Between Groups | 757.41 | 3 | 252.47 | 51.40* |
| | Within Groups | 39.29 | 8 | 4.91 | |
| | Total | 796.71 | 11 | | |
| RE (N mm) | Between Groups | 1071.88 | 3 | 357.29 | 463.98* |
| | Within Groups | 6.16 | 8 | 0.77 | |
| | Total | 1078.04 | 11 | | |

ICF (N) = Initial cracking force of sunflower seed, Newton; MRF (N) = Mean rupture force of sunflower seed, Newton; RE (N mm) = Rupture energy of sunflower seed, Newton millimeter; * Significance at 5% level

**Table 2. Analysis of variance for sunflower kernel to study the significance level for variation in fracture characteristics with moisture content**

| Parameters | Source | Sum of squares | df | Mean square | $F_{Calculated}$ |
|---|---|---|---|---|---|
| ICF (N) | Between Groups | 146.26 | 3 | 48.75 | 115.19* |
| | Within Groups | 3.39 | 8 | 0.42 | |
| | Total | 149.64 | 11 | | |
| MRF (N) | Between Groups | 816.93 | 3 | 272.31 | 20.99* |
| | Within Groups | 103.78 | 8 | 12.97 | |
| | Total | 920.71 | 11 | | |
| RE (N mm) | Between Groups | 141.15 | 3 | 47.05 | 73.58* |
| | Within Groups | 5.12 | 8 | 0.64 | |
| | Total | 146.27 | 11 | | |

ICF (N), Initial cracking force of sunflower kernel, Newton; MRF (N), Mean rupture force of sunflower kernel, Newton; RE (N mm), Rupture energy of sunflower kernel, Newton millimeter; * Significance at 5% level




1. Direction of loading; 2. P-5 test probe; 3. Sunflower seed (var. CO 2); 4. Fixed compression table

**Fig.1. Natural resting position of sunflower seed under compressive loading.**

coefficient of determination ($R^2$) was adequately high, it seems that the moisture content had remarkable influence on the measured parameters.

$ICF_S = -1.098\ M_S + 53.34$ ($R^2 = 0.993$) ……(1)

$ICF_K = -3.114\ M_K + 28.29$ ($R^2 = 0.994$) ……(2)

Where, $ICF_S$ and $ICF_K$ is initial cracking force (N) of sunflower seed and kernel, $M_s$ and $M_k$ is the moisture content (%, d.b.) of sunflower seed and kernel.

***Mean rupture force***

The mean rupture force of sunflower seed and

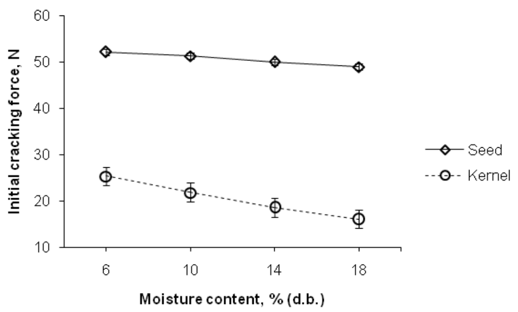



**Fig. 2. Effect of moisture content on initial cracking force of sunflower seed and kernel**

kernel with standard error at 5% significance at different moisture contents are presented in Fig.

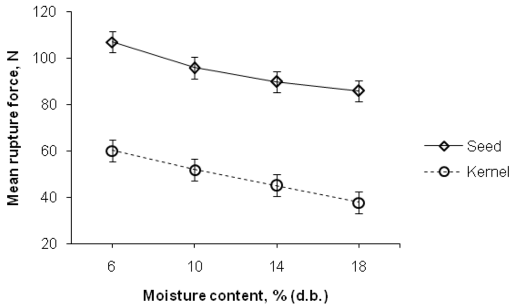



**Fig. 3. Effect of moisture content on mean rupture force of sunflower seed and kernel**

3. The mean rupture force of sunflower var. CO 2 decreased linearly with the increase in moisture content. The mean rupture force of sunflower seed and kernel ranged from 106.91 – 85.86 N and 60.19 – 37.88 N, respectively. While comparing the values of mean rupture force, the values for seed were always found higher than kernel. Similar trend was observed by Bargale *et al.* (1995) for canola and wheat. Table

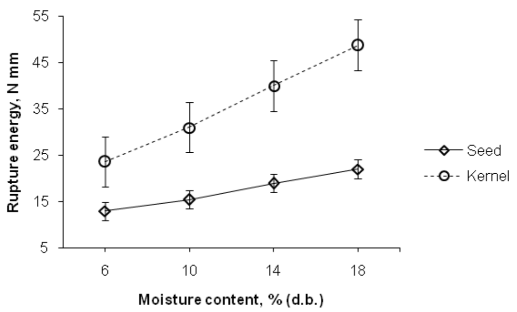



**Fig 4. Effect of moisture content on rupture energy of sunflower seed and kernel**

1 and Table 2 summarized the analysis of variance, which was carried out to investigate the effect of moisture content on mean rupture force for sunflower seed as well as kernel. From the Tables, it is noted that the changes in moisture content significantly influenced the mean rupture force of seed and kernel ($p < 0.05$). Regression equations and their coefficients of determination ($R^2$) obtained for the mean rupture force of sunflower seed and kernel are presented as a function of variety and moisture content in equations 3 and 4. These equations and coefficients confirm a linear behaviour for both sunflower seed and kernel.

$MRF_S = -6.919\ M_s + 111.9$ ($R^2 = 0.948$) ……(3)

$MRF_K = -7.375\ M_k + 67.26$ ($R^2 = 0.998$) ……(4)

Where, $MRF_S$ and $MRF_K$ is the mean rupture force (N) of sunflower seed and kernel; $M_s$ and $M_k$ is the moisture content (%, d.b.) of sunflower seed and kernel.

***Rupture energy***

The variations of rupture energy as a function of moisture content for sunflower seed and kernel with standard error at 5% significance are shown in Fig. 4. The rupture energy of sunflower seed and kernel increased from 23.60 to 48.76 N mm and 12.97 to 22.01 N mm, respectively. Similar to the mean rupture force, the rupture energy was also observed higher in case of seed as compared to kernel at each level of moisture content. Increasing trend may be due to the fact that rupture energy is a function of both force and deformation up to bio-yield point. At low moisture content, the seed requires high force to be ruptured and its deformation was low, but at high moisture content, the rupture force was low and the deformation was high (Khodabakhshain *et al.,* 2010). The increasing trend of rupture energy with increase of moisture content was also documented for some other seeds, such as, safflower and white sesame seed by Khodabakhshian and Shakeri (2012), and Darvishi (2012), respectively. Results of statistical analysis indicated moisture content had significant effect on rupture energy for both seed and kernel at $p < 0.05$ (Table 1 and Table 2). The regression equations and their respective coefficients of determination ($R^2$) for the measured rupture energy of seed and kernel as a function of moisture content are represented in equations 5 and 6.

$$RE_S = 3.061\, M_s + 9.679 \qquad (R^2 = 0.995) \qquad \ldots\ldots(5)$$

$$RE_K = 8.446\, M_k + 14.74 \qquad (R^2 = 0.998) \qquad \ldots\ldots(6)$$

Where, $RE_S$ and $RE_K$ is rupture energy (N mm) of sunflower seed and kernel, $M_s$ and $M_k$ is the moisture content (%, d.b.) of sunflower seed and kernel. These equations confirm that, the experimental data of rupture energy of both sunflower seed and kernel had a good fit with the corresponding moisture content.

## Summery

Initial cracking force of sunflower seed and kernel decreased with increase in moisture content. The mean rupture force also decreased linearly with increase in moisture content from 6 -18% d.b. The rupture energy for both seed and kernel increased linearly with moisture content. Moreover, rupture energy of kernel was lower than seed for all varieties in the whole range of moisture content. Changes in moisture content of sunflower (var. CO 2) seed and kernel exhibited significant effect on its fracture characteristics. This study will be helpful to determine the force and energy required for dehulling and oil expression.

## References


Agritech, TNAU. 2013. www.tnau.ac.in.Agritech.tnau.ac.in/sunflower.pdf. (Accessed on 21.06.2013).

ASAE. 1999. ASAE Standards S352.2. Moisture measurement-unground grain and seeds. ASAE, St. Joseph, MI.

Babic, L.J., Radojcin, M., Pavkov, I., Babic, M., Turan, J., Zoranovic, M. and Stanisic, S. 2013. Physical properties and compression loading behaviour of corn seed, *Int. Agrophys*. **27:** 119-126.

Bamgboye, A. and Adejumo, A. 2007. Development of a sunflower oil expeller, *Agric. Eng. Int.*, **9:** 1-7.

Bargale, P.C., Ford, R.J., Sosulski, F.W., Wulfsohn, D. and Irudayaraj, J. 1999. Mechanical oil expression from extruded soybean samples, *J. Am. Oil Chem. Soc.,* **76:** 223–229.

Bargale, P.C., Irudayaraj, J. and Marquis, B. 1995. Studies on rheological behavior of canola and wheat, *J. Agric. Eng. Res.,* **61:** 267-274.

Baumler, E., Cuniberti, A., Nolasco, S.M., Riccobene, I.C. 2006. Moisture dependent physical and compression properties of safflower seed, *J. Food Engg.,* **72:** 134-140.

Darvishi, H. 2012. Moisture-dependent physical and mechanical properties of white sesame seed. Am-Euras, *J. Agric. & Environ. Sci.,* **12:** 198-203.

Evon, P.H. Vandenbossche, V. Pontalier, P.Y. Rigal, L. 2007. Direct extraction of oil from sunflower seeds by twin-screw extruder according to an aqueous extraction process: Feasibility study and influence of operating conditions, Industrial Crops and Products, **26:** 351-359.

Figueiredo de, A.K., Baümler, E., Riccobene, I.C. and Nolasco, S.M. 2011. Moisture-dependent engineering properties of sunflower seeds with different structural characteristics, *J. Food Engg.,* **102:** 58–65.

Gupta, R.K. Das, S.K. 2000. Fracture resistance of sunflower seed and kernel to compressive loading, *J. Food Engg.,* **46:** 1-8.

Gupta, R.K. Manikantan, M.R. 2006. Rheological properties of NSFH-36 sunflower seed as a function of moisture content and their effect on dehulling of seed, *J. Oilseeds Res.,* **23:** 81-84.

Kang, Y.S., Spillman, C.K. Steele, J. L. and Chung, D. S. 1995. Mechanical properties of wheat, Transactions of the ASAE, **38:** 573-578.

Khodabakhshian, R. and Shakeri, M. 2012. Investigation on some mechanical aspects of safflower seed to the design of processing equipment, *J. Agric. Technol*., **8:** 39-48.

Khodabakhshian, R. Emadi, B. Fard, M. H. A. and Saiedirad, M. H. 2010. Mechanical properties of sunflower seed and its kernel, azargol variety as a case study, under compressive loading, *J. Agric. Sci. Technol*., **4:** 34-40.

Kingsly, A. R. P. Singh, D. B. Manikantan, M. R. and Jain, R. K. 2006. Moisture dependent physical properties of dried pomegranate seeds (Anardana), *J. Food Engg*., **:** 492–496.

Owolarafe, O. K. Olabige, M. T. and Faborode, M. O. 2007. Physical and mechanical properties of two varieties of fresh oil palm fruit, *J. Food Engg*., **78:** 1228-1232.

Saiedirad, M. H. Tabatabaeefar, A. and Borghei, M. 2008. Effect of moisture content, seed size, loading rate and seed orientation on force and energy required for fracturing cumin seed under quasi-static loading, *J. Food Engg*., **86:** 565-572.

Singh, K. K and Goswami, T. K. 1996. Physical properties of cumin Seed, *J. Agric. Engg. Res*., **64:** 93-98.

Sukumaran, C. R. and Singh, B. P. N. 1989. Compression of a bed of rapeseeds: The oil point, *J. Agric. Engg. Res*., **42:** 77-84.

Vursavus, K. Ozguven, F. 2005. Fracture resistance of pine nut to compressive Loading, *Biosystems Engg*, **90:** 185–191.


Received: July 26, 2013; Accepted: November 22, 2013