Int. Agrophysics, 2010, 24, 209-211

INTERNATIONAL
Agrophysics
www.international-agrophysics.org

Note

Restitution coefficient of chick pea and lentil seeds

I. Ozturk, M. Kara, F. Uygan, and F. Kalkan

Department of Agricultural Machinery, Faculty of Agriculture, Ataturk University, 25240-Erzurum, Turkey

Received April 24, 2009; accepted July 10, 2009

A b s t r a c t. The restitution coefficients of chick pea and lentil seeds were determined as a function of moisture content. The effects of grain type, moisture content, impact plate and free fall height on the restitution coefficient of chick pea and lentil seeds were studied. The restitution coefficient of chick pea and lentil seeds decreased as moisture content increased. The difference between values of restitution coefficient of chick pea and lentil seeds was statistically significant. The restitution coefficient of lentil seeds decreased as free fall height increased. The values of restitution coefficient obtained with steel plate were higher than those of fibreglass plate at all moisture content levels for chick pea and lentil seeds.

K e y w o r d s: chick pea, lentil, restitution coefficient

INTRODUCTION

Chick pea (*Cicer arietinum* L.) and lentil (*Lens culinaris* Medik) are common grain legumes which are widely grown and consumed in Turkey. Lentil ranks first in terms of acreage 490 000 ha and production 580 260 t, and chick pea ranks second after chick pea in terms of acreage 500 000 ha and production 523 553 t in Turkey (FAO, 2008).

Restitution coefficient, defined as the ratio of velocity after impact to velocity before impact, indicates the degree of elasticity and plasticity of a particle during its impact on a plate (Hofstee and Huisman, 1990; Mohsenin, 1980; Speelman, 1979). Sharma and Bilanski (1971) determined the restitution coefficient of wheat, corn, pea beans, soybeans, field beans, and red kidney beans falling on a steel plate. Rataj *et al*. (1994) determined the restitution coefficient of two varieties of pea seeds impacting on the plates made of wood, concrete, and steel at different levels of moisture content. They reported that the effect of moisture content on the restitution coefficient of pea seeds was significant, while the effect of the variety and plate type were less significant. Yang and Schrock (1994) investigated the effect of grain type, impact plate angle, seed release height, moisture content, and seed size on resultant restitution coefficient and rebound direction on a steel plate in order to develop a model of a grain kernel impacting on a steel plate. They reported that the resultant restitution coefficient was significantly affected by grain type, impact plate angle, grain release height, while the rebound direction of the grain was significantly affected by the impact plate angle only.

Physical properties such as size, density, porosity, projected area, angle of repose, terminal velocity, coefficient of friction, and rupture strength have been studied for chick pea (Konak *et al.,* 2002) and lentil (Amin *et al.,* 2004; Çarman, 1996). But, no work has been reported by earlier researchers on the restitution coefficient of chick pea and lentil seeds. Therefore this study has been undertaken to determine the restitution coefficient of chickpea and lentil seeds as affected by moisture content.

MATERIALS AND METHODS

Seeds of chick pea (cv. Aziziye 94) and lentil (cv. Erzurum 89) were used in the experiments. The seeds were supplied by the Regional Agricultural Research Institute in Erzurum, Turkey. Four levels of moisture content of the grain were selected as 4.90, 9.50, 16.58, and 21.85% for chick pea, and 5.13, 9.52, 16.07, and 21.77% for lentil. The initial moisture contents of the grain were 9.50% for chick pea and 9.52% for lentil. The lower level of moisture content was obtained by oven drying. The desired moisture contents for higher levels were obtained by adding calculated amounts of distilled water (Yalcin, 2007). Seed samples at the selected levels of moisture content were prepared by adding distilled water into the sample. After mixing and sealing in separate bags

*Corresponding author's e-mail: iozturk@atauni.edu.tr

the seed samples were kept in a refrigerator at 5°C for seven days to enable the moisture to distribute uniformly throughout the sample. Before starting a test, the required quantity of seed was taken out of the refrigerator and then allowed to warm up to room temperature (Çarman, 1996; Desphande *et al*., 1993; Dutta *et al*., 1988). All the tests were carried out at the Biological Material Laboratory in Agricultural Machinery Department of Ataturk University, Erzurum, Turkey.

Experiments with a factorial arrangement of three fall heights by two different impact plates by four moisture content levels by twenty replications within each test were conducted for the chick pea and lentil seeds. Totally 960 tests were performed. Two impact plates, namely steel and fibreglass, were used in the experiments. The thickness of impact plate was 3 mm. The seed was dropped from three heights of 0.5, 1.0, and 1.5 m. The time between subsequent impacts was recorded and then the restitution coefficient (RC) was calculated from the following equation (Sharma and Bilanski, 1971). Air resistance to motion and the rebound angle of the particle were ignored in the study.

$$RC = \frac{V_v}{V_i} = \frac{gt}{\sqrt{2gh}} \quad (1)$$

where: RC – restitution coefficient, V_v – vertical component of rebound velocity (m s^{-1}), V_i – impact velocity (m s^{-1}), g – acceleration due to gravity (m s^{-2}), t – half-time between the first two successive impacts (s), h – free fall height (m).

In order to determine the restitution coefficient, the time between the first and second impacts was measured. The measuring setup had three main components. An impact plate and a tube for dropping the seed from a certain height, a sound sensor for sensing the impact on the impact plate, and a personal computer equipped with data acquisition system. The software by Audacity was used. The seed was dropped from a certain height on the impact plate, the sound sensor sensed the first and second impacts one after the other and the sound signals were transmitted to the personal computer.

RESULTS AND DISCUSSION

Statistical analysis of the data revealed that grain type, moisture content, and impact plate type had significant effects on the restitution coefficient of chick pea and lentil seeds ($p<0.05$). Sharma and Bilanski (1971) reported that the effects of grain type, moisture content, and free fall height on the restitution coefficient were significant. Likewise, Yang and Schrock (1994) reported that the resultant restitution coefficient was significantly affected by grain type. On the other hand, the effect of free fall height on the restitution coefficient was found to be significant for the lentil seeds and insignificant for the chick pea seeds.

The effect of moisture content of chick pea and lentil seeds on restitution coefficient is plotted only at free fall height level of 1 m in Fig. 1. As moisture content increased

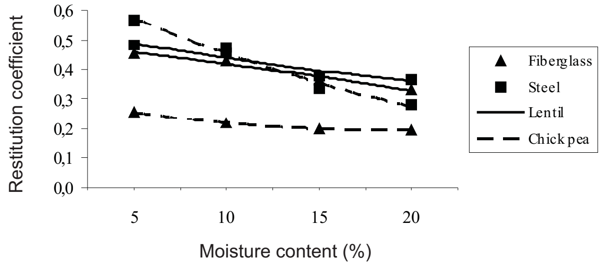

Fig. 1. Effect of moisture content on the restitution coefficient of chick pea and lentil seeds at free fall height of 1 m.

from 4.90 to 21.85%, the restitution coefficient of chick pea decreased sharply from 0.57 to 0.28 for steel plate ($p<0.01$) and decreased from 0.25 to 0.20 for fibreglass plate ($p<0.01$). As seen from Fig. 1, the values of restitution coefficient of chick pea and lentil seeds obtained with the steel plate were higher than those of the fibreglass plate at all moisture content levels. The values of restitution coefficient of lentil seeds decreased sharply from 0.48 to 0.37 for the steel plate ($p<0.01$) and decreased from 0.46 to 0.33 for the fibreglass plate ($p<0.01$) as moisture content increased from 5.13 to 21.77% d.b. The highest restitution coefficient was obtained with the lowest level of moisture content for both grains.

The difference between values of restitution coefficient for chick pea and lentil was statistically significant ($p<0.01$). This can be explained as the differences in geometric and gravimetric properties of the grain (Sharma and Bilanski, 1971). Figure 1 shows that the increase in moisture content resulted in a sharper decrease in the values of restitution coefficient of chick pea seeds than those of lentil seeds at the steel plate. Therefore, the values of restitution coefficient of chick pea seeds were higher at the lower levels of moisture content and lower at the higher levels of the moisture content as compared to those of lentil seeds at the steel plate. On the other hand, the values of restitution coefficient of chick pea seeds were lower than those of lentil seeds at the fibreglass plate. The values of restitution coefficient of both grains obtained with the steel plate are higher than those of the fibreglass plate at all moisture content levels.

The variance analysis revealed that the effect of free fall height on restitution coefficient of chick pea seeds was found to be insignificant, contrary to previous works carried out by Sharma and Bilanski (1971) and Yang and Schrock (1994). The relationship between free fall height and restitution coefficient of chick pea and lentil seeds at the present moisture content is plotted in Fig. 2. Although the values of restitution coefficient of chick pea did not vary as the height of free fall increased for fibreglass plate and the average value restitution coefficient was found to be 0.22 for all levels of free fall height, there was a slight decrease from 0.48 to 0.46 in the values of restitution coefficient at the steel

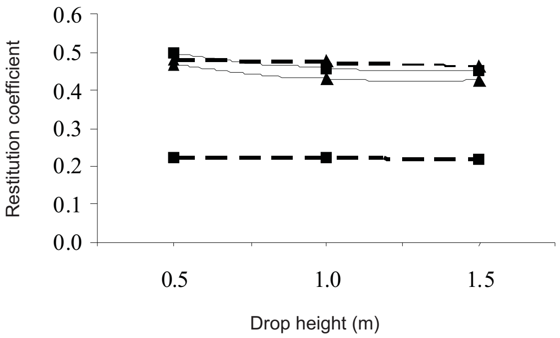

Fig. 2. Effect of free fall height on the restitution coefficient of chick pea and lentil seeds at the present moisture content.

plate as free fall height increased from 0.5 to 1.5 m. On the other hand, the values of restitution coefficient of lentil seeds decreased from 0.49 to 0.45 for steel plate ($p<0.05$) and decreased from 0.47 to 0.43 for fibreglass plate ($p<0.05$) with an increase in free fall height from 0.5 to 1.5 m. A similar relationship was reported in previous works performed by Sharma and Bilanski (1971) and Yang and Schrock (1994). The restitution coefficient of grain decreases because the grain loses more energy during impact as free fall height increases. This energy loss includes elastic and plastic deformation, sound, heat, wave *etc* (Sharma and Bilanski, 1971; Yang and Schrock, 1994).

CONCLUSIONS

1. The effect of free fall height on the restitution coefficient was found to be significant for lentil seeds and insignificant for chick pea seeds.

2. The difference between values of restitution coefficient for chick pea and lentil seeds was statistically significant. The values of restitution coefficient of chick pea seeds were lower than those of lentil seeds for the fibreglass plate.

3. The values of restitution coefficient of chick pea seeds decreased from 0.57 to 0.28 for steel plate and from 0.25 to 0.20 for fibreglass plate as moisture content increased from 4.90 to 21.85% d.b. at the free fall height of 1 m.

4. The values of restitution coefficient of lentil seeds decreased from 0.48 to 0.37 for steel plate and from 0.46 to 0.33 for fibreglass plate as the moisture content increased from 5.13 to 21.77% d.b. at the free fall height of 1 m.

5. The values of restitution coefficient obtained with steel were higher than those of fibreglass at all moisture content levels for both grains.

6. The values of restitution coefficient of lentil seeds decreased from 0.49 to 0.45 for steel plate and from 0.47 to 0.43 for fibreglass plate as the height of free fall increased from 0.5 to 1.5 m.

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