EFFECT OF MOISTURE CONTENT AND BULK DENSITY ON MINIMUM FLUIDIZATION VELOCITY OF LATHYRUS (LATHYRUS SATIVUS L.) GRAIN

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ABSTRACT

The relationship between pressure drop and the rate of airflow through agricultural products is important in design of drying or aeration systems. Pressure drops were measured in Lathyrus (cv. NLK-40, Pratik and Ratan) beds. The respective grain beds were at 7.33 to 18.80%, 6.75 to 18.30% and 7.90 to 19.40% (d. b.) moisture content with bulk density of 805 to 895, 795 to 875 and 770 to 855 kg m⁻³. The pressure drops were measured at 0.2 m bed depth for superficial air velocities ranging from, 0.0421 to 0.9813 m³ s⁻¹ m⁻², 0.0450 to 1.1024 m³ s⁻¹ m⁻² and 0.0484 to 1.1693 m³ s⁻¹ m⁻², respectively, for NLK-40, Pratik and Ratan. With increase in moisture content the minimum fluidization velocity values were found decreased. It was observed that with increase in bulk density the values of minimum fluidization were decreased linearly. The results indicated that 1% increase in moisture content decreased the pressure drop by 3.10%, whereas, 1% increases in bulk density decreased the pressure drop by 7.16%.

Key words : Lathyrus, Moisture content, Bulk density, Fluidization.

INTRODUCTION

Lathyrus (Lathyrus sativus L.) is a food, feed and fodder legume (pulse) crop. In India Lathyrus is also known as khesari, lakhori, lakhodi and chickling pea. The Lathyrus has over the past decade received increased interest as a plant that is adapted to arid conditions and contains high levels of protein. It is grown on an area of about 1.5 million hectares with the annual production of 0.8 million tonnes. Nearly two-third of national acreage under Lathyrus is in southeastern Madhya Pradesh, and in the Vidarbha region of Maharashtra. India ranks first in area (1500 thousand ha), production (800 thousand tonne) and productivity (533 kg ha⁻¹) (Clayton and Campbell, 1997). Rotter et al. (1991) gave the composition for Lathyrus as; energy 362.3 cal, protein 32.6%, fat 2.7%, nitrogen-free extract 51.8%, crude fibre 1.1% and ash 2.2%.

The flow rate at which the particles of the static bed cause incipient fluidization is known as minimum fluidization velocity. From the review of literature it revealed that the data on minimum fluidization velocity for Lathyrus grain is non-existent. For achieving the minimal use of energy in pulse grain drying the optimum air conditions relating to air velocity and temperature is required to be provided to cause the safe moisture loss from the grain bed. Till date the safe maximum drying airflow rate for most of the agricultural grains are not yet reported in the literature. For most of the studies reported so far, it seems that airflow rate considered is not based on the scientific data leading

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to arbitrary selection of the airflow rate. Because of this situation, if the pressure drop data for complete static bed condition i.e. up to the minimum fluidization velocity condition is made available, then the selection of the blower will be more feasible at any level.

Design of efficient systems for drying, aeration and fluidization requires proper design of electric motor and compressor or fan selection, which can only be achieved with information on minimum fluidization of grains. Resistance to airflow is a function of both product and air properties (Khatchatourian and Oliveira, 2006). The air pressure, required to force air through a bed of grain, is dissipated continuously due to friction and turbulence. The pressure drop for airflow through any particulate system depends on the rate and direction of airflow, surface and shape characteristics of the grain, the number, size and configuration of the voids, the particle size range, bulk density, bed depth, method of filling bin, foreign matter concentration and moisture content. The data on the airflow-static pressure relationship of a number of agricultural grains have been published in ASABE (2007). Most of researchers have reported airflow resistance data for agricultural grains but for low ranges of airflow. The data on minimum fluidization as affected by the operating parameters of legume crop are still scarce as reported by Nimkar and Khobragade (2006).

The phenomenon of pressure drop in airflow through agricultural products has been widely investigated for various grains (Nimkar and Mate 2004, Pagano, 2000, Rajabipour et al. 2001, Yang and Williams, 1990, Nimkar and Chattopadhyay, 2003) and root vegetables and other crops (Shahbazi and Rajabipour, 2008, Verboven et al. 2004, Reed, 2001, and Kashaninejad and Tabil, 2009). Earlier reported studies on airflow resistance of different agricultural grains as affected by various operating parameters were reviewed which showed that no design data on the minimum fluidization of Lathyrus is available. Therefore, it was felt necessary to generate and provide information on minimum fluidization of Lathyrus to designers of drying, aeration and fluidization systems by forced draft. The objective of the study was to determine pressure drop at different airflow rates through the clean grain beds of Lathyrus at different levels of moisture content and bulk density.

**MATERIALS AND METHODS**

**Raw material and sample preparation :**

For determination of effect of operating parameters on minimum fluidization of Lathyrus grains three cultivars viz., NLK-40, Pratik and Ratan were evaluated. The conditioning of sample to raise its moisture content to desired level was achieved by adopting the method described by Nimkar and Khobragade (2006). Each of this conditioned test samples was divided into three sub-lots which were used independently to carry out experiments at three different bulk densities in loose, medium and dense packed grain beds. The relevant physical properties viz., moisture content, grain size, true density and bulk porosity were measured with the five representative samples by adopting procedure given by Mohsenin (1986). After filling the required depth of test bin with known mass of grain and volume occupied by them, in-situ bulk density of test sample was determined.

**Minimum fluidization velocity determination**

For the purpose of determination of minimum fluidization velocity the experiments were carried out at three different moisture levels, for NLK-40 7.33, 13.10 and 18.80, Pratik 6.75, 12.50 and 18.30, Ratan 7.90, 13.60 and 19.40 (d. b.) The total grain bed depth filled was 300 mm and pressure drop measurements were taken for the bed depth of 200 mm only as reported by Nimkar and Chattopadhyay, (2003). The experiments were carried out starting from lowest airflow rate and subsequently increasing it till the bed causes incipient fluidization which was recorded as minimum fluidization velocity. The effect of the moisture content and bed density levels on minimum fluidization velocity has been studied.
Experimental procedure

The modified airflow resistance apparatus suitable for determination of pressure drops through beds as reported by Nimkar and Kho bragade, (2006) was used. For determination of the pressure drop through Lathyrus grain the conditioned test sample was removed from the refrigerator and left at room temperature for 6 h so as to equilibrate it with the ambient temperature before use. Test runs were carried out at three bulk densities obtained with loose, medium and densely packed grains. Firstly, the test bed was filled by a loose fill method as described by Lukaszuk et al. (2008). To obtain medium and dense packed bed conditions, initially, a required quantity of test sample was loosely filled and then the bulk density was gradually increased to the desired level by tapping the side walls with rubber hammer.

At each airflow rate, the test run with five sets of observations were conducted at each bulk density level. Relative humidity, atmospheric pressure and temperature were measured five times during each test run and the average was used for airflow rate calculations to standard condition of air at that temperature and pressure. The temperature and relative humidity conditions recorded during the experimentation for NLK-40, Pratik and Ratan were 32.5 ± 1.5°C and 64 ± 3%, 33.1 ± 2.0°C and 74 ± 5% and 36.3 ± 1.5°C and 77 ± 4%, respectively. The data obtained was analyzed with SAS software and graphs were plotted with Excel program.

RESULTS AND DISCUSSION

Characterization of grains

The grain size (Dₘ), in-situ bulk density (Pᵢ), true density (Pᵣ), and bulk porosity (ε) were measured with five representative samples to characterize the grain beds as given in Table 1. The maximum variation of moisture content among the replicated samples was within 0.5%. The variations in bulk density and porosity values among replicated samples were found negligible.

Effect of moisture content on fluidization:

Results obtained showed that for loosely filled NLK- 40 grain bed at the moisture content of

![Fig.1](image)

**Fig.1**: Effect of moisture content on minimum fluidization velocity of Lathyrus cv. NLK- 40 at different moisture contents.
**Fig. 2**: Effect of moisture content on minimum fluidization velocity of Lathyrus cv. Pratik at different moisture contents in loosely filled condition.

**Fig. 3**: Effect of moisture content on minimum fluidization velocity of Lathyrus cv. Ratan at different moisture contents in loosely filled condition.
7.33, 13.10 and 18.80% (d. b.) as shown in Fig. 1; the minimum fluidization velocity values noted were 1.4607, 1.3149 and 1.1886 m³s⁻¹ m⁻², respectively with corresponding increase in moisture content. For loosely filled Pratik grain bed at the moisture content of 6.75, 12.50 and 18.30% (d. b.) as shown in Fig. 2; the minimum fluidization velocity values noted were 1.5317, 1.3935 and 1.2706 m³s⁻¹ m⁻², respectively with corresponding increase in moisture content. Whereas, for Ratan it was observed that for loosely filled grain bed at the moisture content of 7.90, 13.60 and 19.40% (d. b.) and as shown graphically in Fig. 3; the minimum fluidization velocity values noted were found to be 1.5748, 1.4591 and 1.3236 m³s⁻¹ m⁻², respectively, with corresponding increase in moisture content.

With increase in moisture content the minimum fluidization velocity values were found decreased. The moisture content of grain beds were increased which might have resulted change in void configuration along with increased grain surface contact area that has increased the needed airflow rate to cause incipient fluidization for grain with higher moisture content. Similar results have been reported for effect of moisture content on minimum fluidization velocity for various pulse grains for moth gram by Nimkar and Khobragade (2006), black gram (Mate et al, 2009), sorghum by Yang and Williams (1990) and for soybean by Shirkole (2010).

**Effect of bulk density on fluidization:**

The effect of bulk density on minimum fluidization has been reported only for the loose fill condition at middle moisture content because this range of moisture content is generally applied in various legume processing plants. For loosely filled NLK-40 grain beds with moisture content 13.10% (d. b.) and having bulk density of 810, 855 and 900 kg m⁻³ as shown graphically in Fig. 4; the minimum fluidization velocity values were 1.3149, 1.0865 and 0.9422 m³s⁻¹ m⁻², respectively. For Pratik grain bed at the moisture content 12.50% (d. b.) and having bulk density of 800, 845 and 890 kg m⁻³ as shown graphically in Fig. 5; the minimum fluidization velocity values noted were found to be 1.3935,
1.2077 and 1.0900 m$^3$ s$^{-1}$ m$^{-2}$, respectively. Whereas, for loosely filled Ratan grain beds with moisture content 13.60% (d. b.) and having bulk density of 775, 820 and 865 kg m$^{-3}$ as shown graphically in Fig. 6; the minimum fluidization velocity values were 1.4591, 1.3339 and 1.1508 m$^3$ s$^{-1}$ m$^{-2}$, respectively.
With increase in bulk density the minimum fluidization velocity values were found decreased. Increase in bulk density from 810 to 900, 800 to 890 and 775 to 865 kg m\(^{-3}\), at the corresponding moisture content of 13.10, 12.50 and 13.60% (d. b.) for NLK-40, Pratik and Ratan, respectively, the bulk porosity and grain surface contact area was decreased this resulted in the compaction of void configuration which might have lowered the needed airflow rate to cause incipient fluidization. Lowering the needed airflow rate might be due to the composite effect of increased moisture content with increased bulk density values. Similar results have been reported for effect of bulk density on minimum fluidization velocity for various pulse grains for moth gram (Nimkar and Khobragade, 2006), black gram (Mate et al, 2009) and for soybean (Shirkole, 2010).

### CONCLUSIONS

The experimental results showed that the values of minimum fluidization velocity were found linearly decreased with increase in moisture content and bulk density. The results showed that 1% increase in moisture content decreased the pressure drop by 3.10%, whereas, 1% increases in bulk density decreased the pressure drop by 7.16%.

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### REFERENCES


