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# Respiration of pulses stored under different storage conditions

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ABSTRACT

Pulses are a special category crop in a cropping system as well as in human diet due to their ability to fix nitrogen during crop growth and high protein content, respectively. The post-harvest losses of pulses are about 10–30% of their production in the subtropics due to improper storage practices; hence proper storage guidelines and management protocols are needed. The respiration measurement is one way to establish a proper management system for pulses. At combinations of five moisture contents (12, 14, 16, 18 and 20%) and four temperatures (10, 20, 30 and 40 °C), the rate of respiration was determined for pinto bean, chickpea, and green lentil stored for 30 days. Respiration rates increased with increase in moisture content and temperature. Respiration rate was positively correlated with final moisture content and free fatty acid value (FAV) and negatively correlated with seed germination. This study showed that 12–14% wet basis moisture and 10–20 °C are suitable conditions to store pinto bean, chickpea and green lentil for prolonged periods.



## 1. Introduction

Pulses play an important role in meeting global food and nutrition needs. In developing countries, pulses are also termed a "poor man's meat" because of high protein content. After harvest, pulses are stored on farm or in storage facilities prior to processing. During this storage time, pulses undergo many physiological changes that lead to qualitative, quantitative and economic losses. The post-harvest loss is around 9.5% of the total production of pulse grains (Birewar, 1984), in which storage alone is responsible for the maximum loss of about 7.5% compared to other post-harvest losses in developing countries. A household survey in India reported that the maximum storage losses found in chickpea was around 30% and in lentil around 15% (Kumar et al., 2010). Storage losses of pulses often relate to moisture content, seed maturity and storage conditions. Stored-grain moisture content and temperatures are crucial factors in the storage ecosystem. Proper management of these parameters allows safe storage for longer storage periods (Alagusundaram et al., 1990). Normally, pulses are harvested at 20–22% moisture content, dried and stored at 12–14% for 10 months without any losses. Safe storage of pulses depends on the biotic and abiotic factors in the storage structure, mainly temperature and moisture content of grain and relative humidity. Hence, proper monitoring and management of these biotic and abiotic factors help to reduce the qualitative and quantitative losses in stored grains (Jayas, 2012). Pulses are in a suspended state during storage, and under favourable conditions (storage temperature and moisture content) can resume their physiological activity, i.e., respiration. Pulses are hygroscopic in nature and the activity of respiratory metabolism consumes nutrients and oxygen, generates carbon dioxide, water vapour, and releases energy in the form of heat (Daniels et al., 1998; Dillahunty et al., 2000). The respiration rate of pulses or any biological material is closely tied with its metabolic activity which is influenced by both biotic and abiotic factors. Hence, the study of an effect of these factors on the respiration rate of pulses can help to establish the proper monitoring and management practices for safe storage. Also, measurement of respiration rate of stored pulses is an easy, non-destructive means of monitoring the metabolic and physiologic state of the grain. The post-harvest physiology is important for storage suitability, thus many studies have been conducted for measuring respiration. Many researchers correlated stored-grain quality based on intergranular carbon dioxide concentration (Hambleton, 1979; White et al., 1982a,b), or dry matter loss (White et al., 1982a,b; Steele et al., 1969; Hall and Dean, 1978) or its germination capacity (Karunakaran et al., 2001) or both. Respiration rates increase up to a

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certain period and then plateau at a given moisture content and temperature (Dillahunty et al., 2000). Sorour and Uchino (2004) studied the respiration rate of soybean at different storage moisture content and varying temperature and found a constant respiration rate with storage time for low moisture contents. Most respiration studies have been done on cereals and oilseeds and there are limited data on pulses. This study focused on the effect of moisture content, temperature and storage time of three pulses on $CO_2$ production, germination and free fatty acid values (FAV).

The objectives of this experiment were to determine: (1) the respiration rates of pinto bean, chickpea, and green lentil by measuring evolution of $CO_2$ at five moisture contents: 12, 14, 16, 18 and 20% and at four storage temperatures: 10, 20, 30 and 40 °C; (2) the effect of respiration on final moisture content, seed germination, dry matter loss and FAV; and (3) the mathematical relationship between moisture content, storage temperature and respiration rates of pinto bean, chickpea, and green lentil, and to optimize the suitable condition for storage based on the respiration rate.

## 2. Materials and methods

### 2.1. Pulse sample and its preparation

Chickpeas, pinto beans, and green lentils were procured with the assistance of the Pulse Growers Association, Regina, Saskatchewan, with initial moisture content between 11.5 and 12.0% w.b. The initial moisture content was confirmed by ASABE S 352.2 standard hot air oven method (ASABE, 2008) using 15 g of chickpea and pinto bean and 16 g green lentil in a hot air forced convection oven (Model: Lab Companion OF-21E, Geumcheon-gu, Seoul, Korea) at 103 ± 1 °C for 72 h and 130 ± 1 °C for 20 h (Tang and Sokhansanj, 1991), respectively. The samples were conditioned to required moisture levels (12, 14, 16, 18 and 20% w.b.) by adding calculated amounts of distilled water and thoroughly mixing the samples in the rotary mixer for 25–30 min. The samples were sterilized with sodium hypochlorite solution to remove surface microflora. Then the samples were packed in air-tight high density polyethylene (HDPE) plastic bags and stored in a refrigerator (3–4 °C) for 3–4 days to equilibrate the moisture levels.

### 2.2. Experimental setup

About 150 g of seed were placed in 250 ml Erlenmeyer flasks. The glass flasks were sealed with a rubber stopper at top, and the side arm of the neck portion was sealed by a rubber septum with a Nalgene tube inserted to the bottom of the flasks (Fig. 1). These flasks were kept at four temperatures set in four environmental chambers at 10, 20, 30, or 40 °C ± 1 °C and a constant relative humidity of 70 ± 2% with five moisture levels (12–20% w.b.).

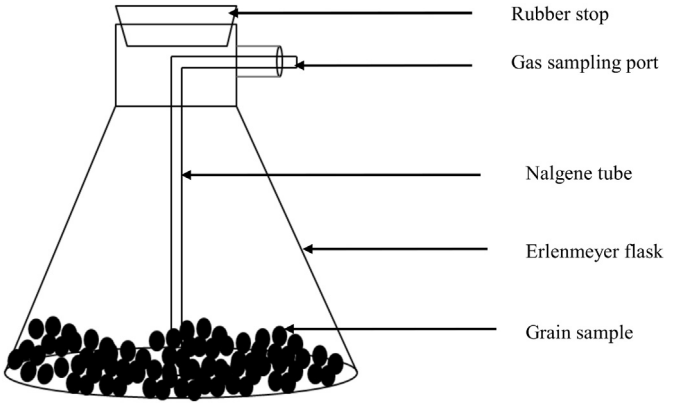


**Fig. 1.** Experimental setup.

### 2.3. Respiration rate measurement

Respiration rate was determined by pulling a 5 ml gas sample from each flask through the inserted Nalgene tube at 3 d regular intervals with a syringe, and a gas chromatograph (Model: Clarus 480, Perkin–Elmer Inc., Shelton, CN, USA) with a thermal conductivity detector, which was connected to HP 3390A integrator (Hewlett–Packard, Palo Alto, CA). After analysis, the flasks were placed back to the respective chambers. The entire experiment was carried out in triplicate. The respiration rate of samples was calculated based on the amount of the $CO_2$ production as:

$$R = \frac{C_C V \rho_C}{100MD} \quad (1)$$

Where,

$R$ = daily $CO_2$ production per unit dry mass of seed (mg/(kg d))
$C_C$ = measured $CO_2$ concentration (%)
$V$ = air volume inside the flask and was calculated as:

$$V = V_{flask} - V_{bulk} + V_{bulk}\varepsilon \quad (2)$$

where,

$V_{flask}$ = volume of the flask (ml)
$V_{bulk}$ = bulk volume of the pulse seeds inside the flask (ml)
$\varepsilon$ = porosity of the pulse seeds (decimal).
$\rho_C$ = density of the $CO_2$ at tested temperatures (mg/ml) (1.908, 1.842, 1.782, 1.725 mg/ml at 10, 20, 30 and 40 °C, respectively)
$M$ = dry mass of the canola seeds inside the flask (kg)
$D$ = airtight time (d)

The bulk volume and porosity was calculated based on the seeds true and bulk densities of the seed by the liquid displacement method (Mohsenin, 1986). Bulk density was determined using the standard test weight procedure (Singh and Gowswami, 1996) by filling a container of 500 ml with the sample from a height of 150 mm at a constant rate and weighing the content (Eq. (3)). Then porosity was determined by using the true and bulk densities of samples (Eq. (5)):

$$\rho_b = M/V_b \quad (3)$$

$$\rho_t = M/V_t \quad (4)$$

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} \times 100 \quad (5)$$

where,

$\rho_b$ is the bulk density of the bulk seeds, kg/m$^3$
$M$ mass of the bulk seeds, kg
$V_b$ is bulk volume of the sample of bulk seeds, m$^3$
$\rho_t$ is the true density of the bulk seeds, kg/m$^3$
$V_t$ real volume of the bulk seeds, m$^3$
$\varepsilon$ is the porosity of seeds, %.

### 2.4. Qualitative parameters

The effect of respiration on pinto bean, chickpea, and green lentil was determined by examining the qualitative parameters