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Effect of moisture content, postharvest treatment, and storage time on some properties and quality attributes of red lentil

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Abstract. *Red lentil (Lens culinaris), an important pulse crop in Canada, is mainly consumed as split or whole cotyledon ("football") with the seed coat removed by dehulling to improve cooking quality and taste. However, related information on the variability in physical properties, chemical* *components and quality attributes of red lentil under different storage conditions are not readily available, which are useful for processors, marketers, breeders, as well as growers. Red lentil of three initial moisture contents of 9.62, 10.07, and 11.31% w.b., were stored for 4 months after different postharvest treatments, including storage at two temperatures of 5□ and 25□. The physical properties, dehulling quality, and cooking quality were investigated at monthly or bimonthly intervals during the 4-month storage period. The 100-seed weight and water absorption were from 2.7591 to 2.7176 g and 101.12% to 98.39%, at a moisture content of 9.62% w.b., respectively, during the 4-month storage period. At the above moisture range, the protein content decreased linearly, while cooking time noticeably increased. The dehulling efficiency varied apparently under different postharvest treatments; red lentil sample stored at 25□ had lower dehulling quality than the sample stored at 5□ within the storage period. The results are necessary for designing equipment for handling, separation, drying and aeration, storage, and processing of red lentil as well as in understanding the effect of storage time and conditions on dehulling and cooking quality of red lentil.*

Keywords. Red lentil, pulse grain, dehulling, moisture content, physical property, postharvest treatment, storage.

Introduction

Lentil (*Lens culinaris L.*), recognized as a valuable pulse grain due to its high content of plant protein with essential amino acids, is known to be one of the most nutritious grain (Raghuvanshi et al., 1994; Bhatty, 1988; Jood et al., 1998). Majority of red lentil is consumed after primary processing (dehulling). The cooking process is the most traditional practice used to convert red lentil into consumable foods.

Recently scientists have made great efforts in evaluating the basic physical properties of agricultural materials (Waziri and Mittal, 1983). Several investigators determined the physical properties, dehulling quality, cooking quality, and nutritional quality of different types of pulses and oilseeds at various moisture contents, such as field pea (Black et al., 1998), lentil (Wang, 2005; Amin, 2004; Isik, 2007; Tabil et al., 1999), flaxseed (Wang et al., 2007; Oomah et al., 1996,); green wheat (Al-Mahasneh and Rababah, 2007), cowpea (Yalcin, 2007); coriander (Coşkuner and Karababa, 2007), safflower (Tabil et al., 1999; Baumler et al., 2006), popcorn (Karababa, 2006), cumin (Singh and Goswami, 1996), and sunflower (Gupta and Das, 1997).

Generally, food legumes are stored for varying periods before processing for domestic consumption. Several changes, which influence the physical properties, dehulling quality, cooking quality, and nutritional quality may occur during storage. However, limited research has been conducted for red lentil under different postharvest treatments and storage periods.

The main objective of this study was to investigate the effect of moisture content, postharvest treatment, and storage time on the dehulling and cooking quality of red lentil. The parameters measured at different moisture contents (9.62, 10.07, and 11.31% w.b.), under different postharvest treatments (5□, 25□) and different storage periods (0, 1, 2, and 4 months) were 100-seed weight, water absorption, dehulling efficiency, cooking time, and protein content.

Materials and Methods

Materials

Red lentil var. 'Robin' used in this study was obtained from an organic grain grower (Pure T Organics) in Regina, Saskatchewan. The red lentil had been gathered three months in advance and kept in a dry place at room temperature before the study. The red lentil was cleaned manually to remove all foreign matter such as dust, dirt, stones, and chaff as well as immature, broken seeds. According to AACC Method 44-15A (AACC, 1995), the initial moisture content of the red lentil was determined by oven drying at 130℃ for 1 h reading to 0.01%. The initial moisture content of the red lentil was 9.62% in wet basis (w.b.). The tests were done at the University of Saskatchewan in the Department of Agricultural and Bioresource Engineering from Feb. 25 to May 30, 2008.

Sample preparation

To determine the effect of moisture content on the physical properties and dehulling quality, the red lentil was tempered to two moisture levels. The desired moisture contents were prepared by adding the amount of distilled water as calculated from the following equation according to AACC Method 26-95 (AACC, 1995):

$$\text{Weight of water to add} = \left(\frac{100 - \text{original moisture (\%)}}{100 - \text{desitred moisture (\%)}} - 1 \right) \times \text{weight of sample} \tag{1}$$

The tempered samples were then stored into separate black polyethylene bags and the bags were sealed tightly. The samples were kept at 5℃ in a cold storage chamber for 10 days to enable the moisture to distribute uniformly. The moisture content of the samples were determined in 3 replicates and expressed in percent wet basis (10.07 and 11.31% w.b.). Then all the samples (9.62, 10.07 and 11.31% w.b.) were packed into Ziploc freezer bags with 2.5 kg red lentils per bag for ease in handling and minimize the influence of moisture content loss for the rest of the samples.

The sample at the initial moisture content (9.62% w.b.) and half of the samples at the moisture content of 10.07% and 11.31% were stored at 5℃ in a cold storage chamber. The other half of the samples at the moisture content of 10.07% and 11.31% were stored at 25℃. Before starting a test, the required quantity of the red lentil was taken out of the storage environment and allowed to equilibrate to the ambient room temperature for about 2 h (Singh and Goswami, 1996; Yalcin and Ozarslan, 2004; Coskun et al., 2006; Isik, 2007).

100-Seed Weight

After the broken and damaged seeds along with foreign material were handpicked from the red lentil sample, one hundred red lentils were randomly counted and weighed using an electronic balance reading to 0.1 mg (Wang, 2005). This measurement was repeated 3 times.

Water Absorption

Water absorption is defined as the maximum amount of water that 100 intact red lentils absorb at room temperature (22±2℃). It was monitored by soaking 100 seeds in distilled water at a ratio of 1:3 (sample mass: water) at room temperature for 16 h. The soaked red lentils were blotted with a paper towel to remove excess water and weighed. Water absorption was expressed as a percent of water absorbed per gram of red lentil and calculated using the following formula (Wang, 2005; Black et al., 1998):

$$\text{Water absorption} = \frac{(W_2 - W_1) \times 100}{W_1} \% \qquad (2)$$

Where W_1 is the initial mass of the sample and W_2 is the mass of sample after absorption. This measurement was repeated 3 times.

Dehulling Efficiency

Red lentil sample (100 g) was tempered to 12.5% moisture before dehulling (Wang, 2005). A grain testing mill (TM05C, Satake Engineering Co., Hiroshima, Japan) was employed for determining the dehulling efficiency. The abrasive wheel was operated at 1100 rpm and 30 g of red lentil sample was processed in the mill for 38 s. After dehulling, the product was separated into whole seeds, split seeds, broken seeds, and hulls manually. Both split and whole seeds were further separated by hand into their respective hulled and dehulled classes. Dehulled seeds refer to the sample displaying with 2% or less seedcoat adherence following dehulling (Bruce, J. 2008. M. Sc. Student. Personal communication). Dehulling efficiency (%) was defined by the percent of dehulled whole seeds (%) and dehulled split seeds (%) obtained relative to the initial sample mass (Wang, 2005). This measurement was repeated 3 times.

Cooking Time

Prior to cooking, red lentil samples (30 g) were soaked in distilled water at room temperature (22 ±2℃) for 24 h. An automated Mattson cooker (Canadian Grain Commission, Winnipeg, MB), consisting of a cooking rack and 25 hollow plungers, was used to determine the cooking time of the individual red lentils. Soaked red lentils were positioned into each of the 25 perforated depression of the rack so that the stainless steel rod of the 90 g plunger was in contact with the surface of the red lentil. The rack was then placed into a 2 L metal beaker containing 1.2 L of boiling water. Red lentils were judged as 'cooked' when the 2.0 mm diameter rod of the plunger pierced the red lentil and dropped through the perforation in the cooking rack. The time taken for each plunger to drop was automatically recorded. Cooking time for a sample was defined as the time required for 80% of the red lentils to be penetrated (Wang, 2005). This measurement was repeated 3 times.

Protein Content

Total protein content was estimated by determination of the total nitrogen content of the sample, where % protein = N content (%) ×6.25 (Williams et al., 1998; Black et al., 1998; Wang, 2005). The nitrogen content analysis was carried out with the ground mixed samples using the standard AOAC procedures (AOAC, 2005). For protein content measurement, two replicates were used.

Statistical analysis

The analysis was carried out based on the experimental data by using the SPSS (SPSS Inc., Chicago, ILL.) and Microsoft Office Excel (Microsoft Corp., Redmond, WA) statistical packages.

Results and Discussion

100-Seed Weight

The mean values and standard deviations of 100-seed weight of the red lentil at different moisture contents under different postharvest treatment and storage periods are presented in Table 1. As could be observed, the 100-seed weight increased with the increasing moisture content and the increasing storage temperature in the range of 9.62-11.31% (w.b.) and 5-25℃, respectively. However, as the storage time increased, the values of 100-seed weight obviously decreased. Thus, the highest and lowest values were observed on the initial sample stored at 25℃ in the moisture content of 11.31% and the sample stored at 5℃ in the moisture content of 9.62%, respectively for 4 months storage. Decreases of 0.51%, 0.93%, 0.88% and 1.75% in the 100-seed weight were recorded for the red lentil stored at 5℃ and 25℃ in the moisture content of 10.07% and 11.31%, respectively, for 2 months storage.

Table 1. 100-seed weight of red lentil at different moisture content under different postharvest treatment and storage time.

Sample (Moisture content, % w.b. and postharvest treatment)	100-seed weight (g)			
	Storage Time (month)			
	0	1	2	4
9.62% 5℃[a]	2.7591±0.0107[c]	2.7463±0.0016	2.7342±0.0084	2.7176±0.0051
10.07% 5℃	2.7829±0.0410	2.7768±0.0152	2.7748±0.0166	2.7687±0.0045

10.07%	25℃[b]	2.8183±0.0066	2.7987±0.0379	2.7920±0.0134	------
11.31%	5℃	2.8434±0.0380	2.8228±0.0128	2.8185±0.0197	2.8118±0.0141
11.31%	25℃	2.8748±0.0090	2.8420±0.0086	2.8245±0.0167	------

[a] The sample at the moisture content of 9.62% stored at 5□.
[b] The sample at the moisture content of 10.07% stored at 25□.
[c] Mean value ± standard deviation based on 3 replications.

Water Absorption

The water absorption of red lentil at different moisture contents under different postharvest treatments and storage periods are shown in Figure 1. Apparently, the amount of water absorption for all the samples decreased with the increasing moisture content of red lentil within the first 2 months. However, for samples stored at 5℃, water absorption slightly increased from 97.90 to 98.39%, 96.82 to 97.39%, and 94.00 to 95.50%, respectively, for an increase in moisture content from 9.62% to 11.31% (w.b.) between 2 months and 4 months storage. This may be due to ignoring of correction for dry weight loss into the soaking water and the decreasing trend in dry weight loss with the increasing storage time. Parrish and Leopold (1978) have shown that water absorption data on seeds may be misinterpreted if water absorption was recorded as a percentage of the initial fresh weight without correcting for dry weight loss during soaking. The overall trend for water absorption of al samples was decreasing within the storage time.

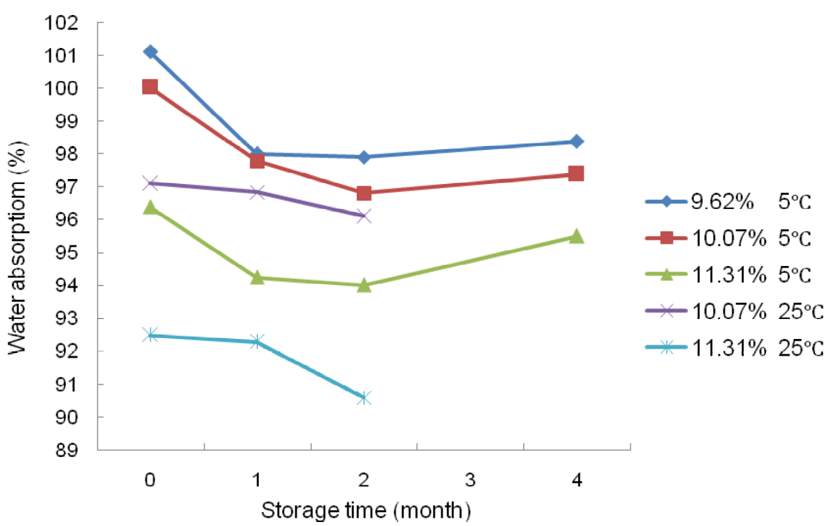

Figure 1. Change in water absorption (%) during 4 months storage time.

Dehulling Efficiency

The change of dehulling efficiency of red lentil at different moisture contents under different postharvest treatments and storage periods is given in Table 2. The dehulling efficiency of red lentil decreased with storage time, storage temperature, and the moisture content. Significant differences ($P < 0.05$) in the dehulling efficiency of red lentil were observed for both the postharvest treatment and storage time. The dehulling efficiency of lentil stored at 5□ at the moisture content of 9.62% for 0 month was the highest (86.78%); while the dehulling efficiency of lentil stored at 25□ at the moisture content of 11.31% was only 85.10% after 2 months storage.

Table 2. Effect of moisture content and postharvest treatment on dehulling efficiency (%) of red lentil over 0, 1, 2 and 4 months of storage

Sample (Moisture content, % w.b. and postharvest treatment)	Dehulling Efficiency (%)			
	Storage Time (month)			
	0	1	2	4
9.62% 5℃[a]	86.77	86.66 a	86.53 a	86.51 a
10.07% 5℃	86.72	86.65 a	86.54 a	86.46 a
10.07% 25℃[b]	86.49	86.23 b	86.33 a	------
11.31% 5℃	86.71	86.12 b	85.77 b	85.75 b
11.31% 25℃	86.27	85.60 c	85.10 c	------

[a] The sample at the moisture content of 9.62% stored at 5□.
[b] The sample at the moisture content of 10.07% stored at 25□.
Note: Values (mean of three replicates) in the same column followed by the same letter are not significantly different by Duncan's multiple range test ($P < 0.05$).

Cooking Time

Some researchers studied the relationship between seed size and cooking time, and between the water absorption and cooking quality. Williams et al. (1983) reported a positive and significant correlation between seed size and cooking time for chickpea. Bishnoi and Khetarpaul (1993) reported that higher water absorption for pea was associated with shorter cooking time. In this study, similar trends were observed.

The cooking time for red lentil during 4 months' storage are shown in Table 3. As could be observed, the cooking time increased with the increase in both moisture content and storage time. This could be due to the increase in the 100-seed weight. This observation agrees with the previous studies for the cooking time of black bean (Jackson and Varriano-Marston, 1981). The red lentil sample stored at 25℃ exhibited longer cooking time than the samples stored at 5℃. These results confirm the previous reports that storage at higher temperature increased the time required to cook red kidney bean (Moscoso et al., 1984), also defined as 'hard-to-cook' phenomenon, which has been shown to be the result of physical and chemical changes that occur at the intercellular level during storage (Hohlberg and Stanley, 1987), resulting in an increase in cooking time as extended storage under high temperature and high relative humidity conditions (Reyes-Moreno and Paredes-Lopez, 1993; Hohlberg and Stanley, 1987; Jackson and Varriano-Marston, 1981).

Table 3. Effect of moisture content and postharvest treatment on cooking time (min) of red lentil over 0, 1, 2 and 4 months of storage.

Sample (Moisture content, % w.b. and postharvest treatment)	Cooking time (min)			
	Storage Time (month)			
	0	1	2	4
9.62% 5℃[a]	1.595	1.947	2.403	3.057
10.07% 5℃	1.651	2.213	2.700	3.309
10.07% 25℃[b]	1.991	2.338	2.946	------
11.31% 5℃	1.940	2.797	3.266	3.773
11.31% 25℃	2.350	2.923	3.365	------

[a] Sample at the moisture content of 9.62% stored at 5□.
[b] Sample at the moisture content of 10.07% stored at 25□.

Protein Content

The experimental data for protein content of red lentil at different moisture contents under different postharvest treatments and storage periods are shown in Figure 2. It was observed from Figure 2 that the protein content of red lentil stored at 5℃ decreased with an increase in storage time. However, the protein content of the lentil stored at 25℃ increased within 2 months storage.

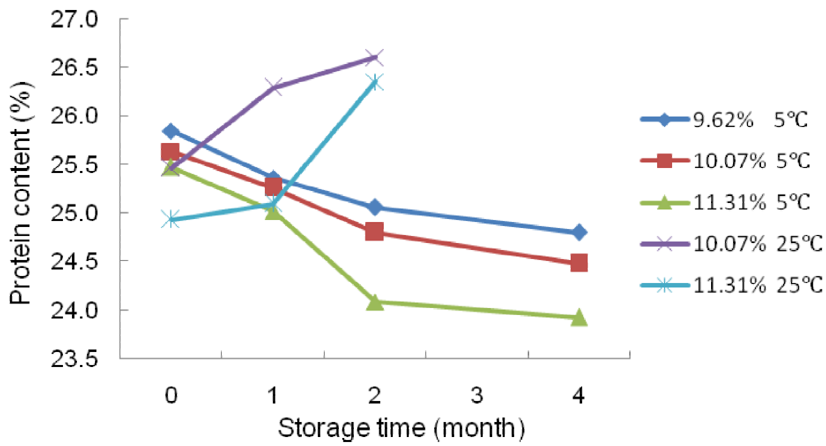

Figure 2. Change in protein content (%) during 4 months storage time.

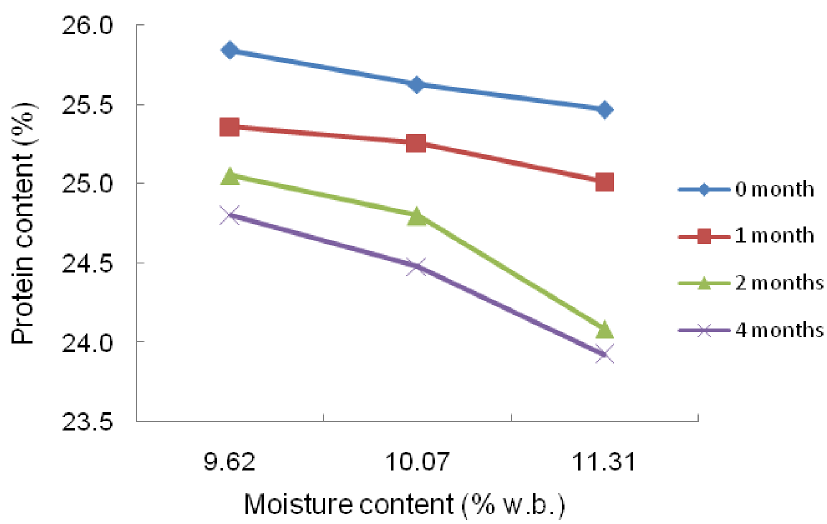

Figure 3. Effect of moisture content on protein content (%) of the red lentil stored at 5℃.

Figure 3 gives the experimental data of protein content performed on different moisture content of lentil stored at 5℃. The relationships between protein content and moisture content over 0 (P_{c0}), 1 (P_{c1}), 2 (P_{c2}) and 4 (P_{c4}) months' storage could be represented by the following equations:

$$P_{c0} = 0.277 - 0.202M_c \quad (R^2 = 0.88) \qquad (3)$$

$$P_{c1} = 0.273 - 0.203M_c \quad (R^2 = 1.00) \tag{4}$$

$$P_{c2} = 0.306 - 0.575M_c \quad (R^2 = 1.00) \tag{5}$$

$$P_{c4} = 0.296 - 0.503M_c \quad (R^2 = 0.99) \tag{6}$$

Conclusions

From the experiments, the following conclusions are drawn:

- Considering moisture content only, the 100-seed weight and the cooking time of red lentil increased in the moisture content range; while the ability of water absorption, dehulling efficiency, and protein content decreased in the moisture content range.
- Considering postharvest treatment and storage time, the protein content of red lentil stored at 5℃, 100-seed weight, water absorption, and dehulling efficiency decreased within the storage period, while positive trends in the protein content for the red lentil stored at 25℃ and the cooking time were found during the storage period.
- High temperature and long storage time adversely affect the dehulling quality and cooking quality of red lentil.
- Further studies should be conducted on more variability of chemical and nutritional properties under different postharvest treatments and different storage time, such as the contents of starch, phytic acid, and calcium, to better understand the influence factors on cooking quality of red lentil. Also a wider moisture range and longer storage time should be involved in further studies.

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