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Effect of microwave drying and storage on the color, breakage, dehulling and cooking quality of two red lentil varieties

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Abstract. *Red lentil is a nutritious and healthy food which provides nutritional and health benefits to consumers. Lentils should be harvested from the field at higher moisture content and dried to lower storage moisture content to reduce field shattering losses during harvesting. Drying and storage might affect the processing quality of lentils. Color characteristics, breakage susceptibility, dehulling, and textural cooking quality of microwave dried, convection dried and undried Robin and Impact red lentils were determined. The lentils were stored at 5^{o}C for about 11 months. The color of the samples was determined using Hunterlab spectrocolorimeter (Hunter Associates Laboratory Inc., Reston, Virginia, U.S.A.). The Stein breakage test was used to determine the breakage susceptibility of the lentils. Satake mill was used to dehull the samples at a speed of 1100 rpm for 38 s. The samples were soaked for 24 h and cooked for 2, 3, and 4 min. A texture analyzer (Texture Technologies Corp., Scarsdale, NY) was used to determine the cohesiveness and the hardness of the lentil samples. Storage had a marked influence on the color change of the Robin and Impact lentils dried at 70^{o}C. The total color change was higher for the Robin and Impact lentils dried at 70^{o}C compared to the microwave dried lentils. There were significant variations in the breakage susceptibility of the stored lentils. The breakage susceptibility of the lentils was influenced by the lentil variety as well as the drying method. The undried and microwave dried lentils had higher dehulling efficiency compared the convection dried samples. The Impact lentils produced higher split dehulled kernels and lower whole dehulled kernels compared to the Robin lentils. Cooking time did not have significantly influence on the cohesiveness of most of the lentil samples. The cohesiveness of the Impact lentils tended to be slightly higher than the Robin lentils by comparison. The cohesiveness values for the Robin lentils ranged from 0.18 to 0.25 and the Impact* *lentils varied from 0.23 to 0.28. Cooking time did not markedly affect the hardness of most of the lentil samples. By comparison, the Impact lentils tended to produce higher hardness values compared to the Robin lentils. The hardness of the Robin lentils ranged from 5.38 to 16.01 N and the Impact lentils ranged from 6.25 to 35.03 N.*

Keywords. Red lentils, breakage susceptibility, color, cooking quality, texture, dehulling, hardness, cohesiveness

Introduction

Canada is one of the leading producers of lentils and the leading exporter. On the average, Canada earns about $240 million (Canadian) yearly from exporting lentils (Saskatchewan Pulse Growers 2005). Red lentil is a nutritious and healthy food which provides a good source of proteins, vitamins, minerals (potassium, iron, calcium, phosphorus and zinc), and fibre and low in fat (Solanki et al. 1999; Bhatty 1988; Savage 1988). It provides nutritional and health benefits to consumers. Health benefits derived from consuming lentils include reduction in coronary heart disease, preventing iron deficiency and stabilizing blood sugar (Leterme 2002).

Lentils can be swathed when about one-third of the pods start to turn yellow and the seeds rattle in the pods. On the other hand, straight cutting of lentils can be done when the pods and seeds are fully mature. To reduce lentil shattering losses during harvesting, it is normally recommended to thresh lentils at around 16 to 20% wb (wet basis). The lentils should then be dried down to 13 to 14% wb to produce high quality seeds for safe storage and to reduce subsequent mechanical damage and breakage susceptibility during handling and processing (Tang et al. 1990b; Tang et al. 1992).

Microwave drying, compared to conventional convection drying of lentils, is energy efficient and rapidly heats dielectric materials and it is used for drying, heating, thawing, sterilization, and food/feed processing operations (Decareau 1986). Microwave drying is being explored as an alternative method of drying for lentil. Microwave drying as well conventional drying might induce stress cracks in the dried product which might affect further processing and handling of the product (Tang et al., 1990a; Tang et al., 1991). Cracked and damaged seeds may break during dehulling resulting in low quality product. Damaged lentil seeds may lower the grade of the product commanding a lower price. Storage may increase the hardness of the seeds affecting the cooking quality of the seeds.

Lentils with dark brown color might be considered low quality so it is essential to determine the effect of microwave drying and storage on the color. Color plays an important role in the acceptability of a dried product by consumers. The Canadian Grain Commission (2008) recommends the use of approved color guides for color grading of lentils. The color of lentils might vary from light tan to brown or very dark brown. Lentils with dark brown color might be considered low quality.

The objectives of these experiments were to determine effect of storage on the processing characteristics of microwave and convection dried red lentil varieties, Robin and Impact. The processing characteristics that were determined were color, breakage, dehulling, and textural cooking qualities of the red lentils.

Materials and Methods

Materials

Two red lentil (Robin and Impact) varieties were used in these experiments. The Robin lentils were obtained from Pure T. Organics, Regina, SK and the Impact lentils were supplied by Reisner Seed Farm, Limerick, SK. The initial moisture content of the lentils was determined by using the method developed by Tang and Sokhansanj (1991c). About 16 g of a sample was dried at 130^{o}C for 20 h. The initial moisture contents of Robin and Impact lentils were determined to be 9.85% and 6.50% wb, respectively. The samples were placed in containers and calculated amount of water was sprayed on the lentils to bring the moisture content around 20%. After adding water, the containers were placed in a concrete mixer and rotated for about 5 h. The samples were then placed in walk-in storage room maintained at 5^{o}C to equilibrate for 1 week. The moisture contents of the conditioned samples were determined after 1 week equilibration. The moisture contents of the conditioned samples were determined to be 20.82% for the Robin variety and 21.86% for the Impact.

Microwave drying

A combined microwave-convective dryer, Panasonic Model NNC980W (Panasonic Canada Ltd, Mississauga, ON) was used in drying the lentils. For microwave drying, about 700 g of lentils was weighed and placed on 381 mm circular ceramic plate. The lentils were spread on the ceramic plate to a diameter of 343 mm and a height of 10 mm. The lentils were dried intermittently at 3 min intervals until the required moisture content was reached. After every 3 min of drying, the lentils were removed, weighed, and mixed together. Before drying the sample, the microwave oven was preheated for 10 min by placing about 2000 g of water. Three power levels, P10 (713 W), P7 (606 W) and P4 (330 W) were used for the microwave drying. The dried samples were cooled at 5°C for 10 min before placing them in re-sealable plastic bags and storing at 5°C.

Convective oven drying

A mechanical convection oven (Model 28, Precision Scientific Group, Chicago, IL) was also used to dry the lentil samples. The samples were dried at 70°C until the desired moisture content was reached. Two samples of about 700 g each were placed in the oven and dried at the same time. The samples were removed and weighed at 20 min intervals. The dried samples were cooled for 10 min before storing at 5°C.

Storage of lentils

The dried (microwave and convection) lentil samples were placed in Ziploc bags and placed in a refrigerated storage room. The temperature in the storage room was maintained at 5°C with relative humidity at 85%. Original Robin and Impact lentils were conditioned to 12.51% and 12.34% moisture contents, respectively. The samples were also placed in Ziploc® double zipper bags and placed in the storage room. The samples were stored for approximately 11 months. Before color, dehulling, breakage and cooking quality tests the samples were brought to room temperature (22 – 24°C).

Color parameters

The color of the lentil samples was measured using Hunterlab spectrocolorimeter (Hunter Associates Laboratory Inc., Reston, VA). After initial calibration against standard black and white surface plates, four measurements for each sample were taken. Color change, ΔL, Δa, and Δb values were calculated. The total color change (ΔE) is calculated using the L, a, b color coordinates and as defined by the Equation 1 (Maruyama et al. 2001).

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2} \qquad (1)$$

The base (standard) values of Hunter L, a, and b represent that of the fresh (undried) sample. The Hunter "L" value represents the lightness or darkness of a sample on a scale of 0 to 100 (100 being white and 0 being black). Hunter "a" value represents the greenness or redness of the sample (-50 being green and +50 being red). Hunter "b" value is also rated on a scale of -50 to +50, with -50 representing blue and +50 representing yellow. The Hunter values prefixed by a greek delta (Δ) represent the difference of the base value from the dried and stored sample measured value. One-way analysis of variance was used to test the significance of the results at 5% and Tukey's HSD was used to compare the means.

Breakage susceptibility of lentils

The Stein breakage tester (Model CK2-M, Fred Stein Laboratories, Inc., Atchison, KS) was used to test the breakage susceptibility of the lentil samples. Before the tests, the samples were pre-sieved using a 3.57 mm (9/64 in.) round-hole screen recommended by Canadian Grain Commission for normal cleaning of small lentils (Canadian Grain Commission, 2008). About 100 g sample was placed in a cup and the tester was run at a speed of 1725 rpm for two minutes. After the test, the sample was collected and sieved using 3.57 mm screen. The sample remaining on the screen was collected and weighed. The breakage susceptibility was determined as ratio of the mass passing through the screen after the test to the original starting mass. Three replicates were conducted for each sample.

Dehulling of lentil

A Satake grain milling machine (TM05C, Satake Engineering Co., Hiroshima, Japan) was used for dehulling the lentil samples. The mill was run at a speed of 1100 rpm. About 30.0 g of lentil sample was processed in the mill for 38 s. After dehulling, the product was separated into fines, whole dehulled seeds, split dehulled seeds, undehulled seeds, and hulls. The dehulled sample was sieved using a No. 20 mesh sieve (0.84 mm) and the fraction passing through the sieve was defined as fines. The hulls were then removed by an aspirator (Style No. CFZ1, Carter-Day Company, Minneapolis, MN). The dehulled seeds were then manually separated from the undehlled seeds. Dehulled split and whole seeds were further separated using a rectangular sieve 1.98 x 19.05 mm (5/64 x 3/4 in). Dehulled seed was defined to the sample with 10% or less seedcoat adherence following dehulling. Dehulling efficiency (%) was defined by the percent of dehulled whole seeds and dehulled split seeds obtained relative to the initial sample mass (Wang, 2005). Three replicated measurements were done for each sample.

Textural cooking quality of lentil

The textural quality of the lentils after cooking was determined by using a texture analyzer (Texture Technologies Corp., Scarsdale, NY) with a load cell capacity of 25 kg. Texture Expert Exceed software (Stable Micro Systems Ltd., Surrey, UK) was used to acquire and analyze the force, time and displacement data. Two-cycle texture profile analysis (TPA) compression test was used. The parameters for the compression tests were set as follows: pre-test speed =1 mm/s, test speed = 0.5 mm/s, post test speed = 1 mm/s, trigger force = 5.0 g, compression distance after trigger force = 1.8 mm. Twenty-five cooked lentil samples were used for the texture profile analysis. The lentils were soaked at room temperature for 24 h and then they were cooked for 2, 3, and 4 min at a boiling water temperature of 98.6^{o}C. The compression tests were conducted at room temperature. A cylindrical aluminum probe with a diameter of 38.1 mm (1.5 in) was used to compress the samples on a table parallel to the probe's compression surface.

Textural quality characteristics of the cooked lentils that were determined included hardness and cohesiveness. Hardness is the maximum force reached during the first-cycle compression of the product (Ma et al. 1998). Cohesiveness of the product is determined from the ratio of the positive compression area under the second compression to the positive area under the first compression curve up to the point of maximum compression excluding decompression area and any adhesiveness area (Bourne and Comstock, 1981).

Results and Discussion

Lentil moisture content

The moisture content of the lentils used in the various tests is presented in Table 1. The moisture content of the Robin lentils varied from 12.06% to 12.51% and that of the Impact lentils ranged from 12.13% to 12.50%. Statistically, there were variations in the moisture content of the samples used for the experiments.

Stored lentil color characteristics

Table 2 shows the color characteristics of the dried and stored red lentils. The results show that there were significant variations in the color of the lentils samples from drying and storage. The Robin samples became lighter and this was pronounced among samples dried at 70^{o}C. The ΔL values for the stored Robin lentils ranged from -7.34 to -0.20 compared to the values before storage which varied from -0.88 to1.62 (Opoku et al., 2008). The Robin samples dried with the microwave were redder and yellowish compared to the samples dried at 70^{o}C. The Robin samples dried 70^{o}C had the highest total color change of 9.73 compared to a value of 0.92 before storage. For the Robin lentils, the total color change for P4, P7, P10, and convection dried were 0.86, 1.23, 1.29, and 9.73, respectively, compared to values of 1.72, 1.62, 1.44, and 0.92 before storage.

The Impact lentils dried 70^{o}C showed similar color change characteristics as the Robin samples dried at 70^{o}C. The convection dried sample became much lighter than the microwave dried samples. The microwave dried samples became yellowish while the convection air dried samples became bluish. The total color change for convection dried sample was the highest. For the Impact lentils, the total color change for P4, P7, P10, and convection dried were 1.86, 1.30, 3.78, and 9.47, respectively, compared to values of 2.41, 1.11, 2.05, and 4.45 before storage.

Breakage susceptibility of lentils

Figure 1 shows the breakage susceptibility of the lentil samples after storage. The results show that there were significant variations in the breakage susceptibility of the stored sample. The original Robin and Impact lentil samples produced lower breakage compared to the dried samples. The Impact lentils had higher susceptibility to breakage than the Robin lentils. For the Robin lentils, breakage susceptibility decreased with increasing microwave power levels. The convection dried lentils (Robin and Impact) had lower breakage susceptibility than the microwave dried lentils. The breakage susceptibility of the lentils may depend on the lentil variety as well as the drying method. Tang et al. (1991a) determined the breakage susceptibility of harvested Laird lentils and reported that at a temperature of 22^{o}C and moisture content of 12.2%, the expected breakage susceptibility would be 17.12%. The samples were dried at 30^{o}C and relative humidity of 5%. Tang et al. (1991b) determined the effect of convection drying and six-month storage on the breakage susceptibility of Laird lentils. The samples were dried to a moisture content of 13.5%. They reported that storage resulted in about 2 to 5% increase in breakage. Increasing the drying temperature tended to reduce the breakage.

Dehulling characteristics of lentil

The dehulling characteristics of the dried and the original undried lentils after storage are presented in Table 3. The results show the method of drying affected significantly the dehulling characteristics of the lentil samples. For the Robin lentils, the convection dried sample had the highest undehulled seeds resulting in the lowest dehulling efficiency compared to the other samples. The undried Robin lentil produced the highest whole dehulled and the lowest split dehulled kernels. The contrary was produced by the Robin lentils dried at power level 4 (P4). There was no significant difference between the dehulling efficiency of the microwave dried and undried Robin lentils.

For the Impact lentils, the convection dried sample had the highest undehulled seeds resulting in the lowest dehulling efficiency compared to the other samples. The undried Impact lentil produced the highest whole dehulled and the lowest split dehulled kernels. The contrary was produced by the Impact lentils dried at 70^{o}C. There was no significant difference between the dehulling efficiency of the microwave dried and undried Impact lentils. The Impact lentils produced higher split dehulled kernels and lower whole dehulled kernels compared to the Robin lentils. Oomah and Mazza (1998) reported that microwave drying affected the dehulling of flaxseed. Samples that were microwave-treated produced higher yields of medium and hull fractions than untreated seeds. They indicated microwave drying proved to be a useful conditioning treatment for achieving high yields of hulls and cotyledons.

Textural cooking quality of lentil

The cohesiveness of the cooked lentils samples is presented in Table 4. For the Robin lentils, the cooking time did not affect the cohesiveness except the original undried samples. The undried Robin samples cooked for 3 to 4 min had higher cohesiveness values compared to the other samples. The cohesiveness values for the Robin lentils ranged from 0.18 to 0.25. For the Impact lentils, the cooking time did not significantly affect the cohesiveness of the samples. The cohesiveness values for the Impact lentils ranged from 0.23 to 0.28. The cohesiveness of the Impact lentils tended to be slightly higher than the Robin lentils by comparison. Sareepuang et al. (2008) reported cohesiveness values for cooked parboiled rice as 0.42 to 0.47. These values for rice seem slightly higher than the values obtained for the cooked lentils.

The hardness values of the cooked lentils are presented in Table 5. Cooking time did not significantly influence the hardness of the Robin lentils except the microwave dried sample at power level 7 (P7). The hardness of values of the Robin lentils tended to slightly decrease with cooking time. The undried Robin lentils produced lower hardness values compared to the other samples. The microwave dried Robin lentils had higher hardness values compared to the undried and convection dried lentils. The hardness of the Robin lentils ranged from 5.38 to 16.01 N. Cooking time did not significantly influence the hardness of the Impact lentils except the microwave dried sample at power level 4 (P4). The hardness of values of the Impact lentils did not show a clear trend with cooking time. The undried Impact lentils produced lower hardness values compared to the other samples. The microwave dried Impact lentils had higher hardness values compared to the undried and convection dried lentils. The hardness of the Impact lentils ranged from 6.25 to 35.03 N. By comparison, the Impact lentils tended to produce higher hardness values than Robin lentils. Scanlon et al. (1998) pretreated Laird lentils and cooked the samples for different times. They reported the hardness values as 56.3, 33.3, and 26.6 N for cooking times of 30, 40, and 50 min.

Conclusions

The following conclusions can be drawn from the experiments conducted on microwave dried, convection dried and undried lentils after storage:

1. Storage had a marked influence on the color change of the Robin and Impact lentils dried at 70°C. The total color change was higher for the Robin and Impact lentils dried at 70°C compared to the microwave dried lentils.
2. There were significant variations in the breakage susceptibility of the stored lentils. The breakage susceptibility of the lentils was influenced by the lentil variety as well as the drying method.
3. The undried and microwave dried lentils had higher dehulling efficiency compared to the convection air dried samples. The Impact lentils produced higher split dehulled kernels and lower whole dehulled kernels compared to the Robin lentils.
4. Cooking time did not have significantly influence on the cohesiveness of most of the lentil samples. The cohesiveness of the Impact lentils tended to be slightly higher than the Robin lentils by comparison. The cohesiveness values for the Robin lentils ranged from 0.18 to 0.25 and the Impact lentils varied from 0.23 to 0.28.
5. Cooking time did not markedly affect the hardness of most of the lentil samples. By comparison the Impact lentils tended to produce higher hardness values compared to the

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Robin lentils. The hardness of the Robin lentils ranged from 5.38 to 16.01 N and the Impact lentils ranged from 6.25 to 35.03 N.

6. Microwave drying produced enhanced quality lentils in terms of color and dehulling characteristics compared to the convection air dried lentil samples.

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Table 1. Moisture content of the lentil samples used in the experiments.

Treatment	Moisture content (% wet basis)	
	Robin lentils	Impact lentils
Original	12.51b	12.34ab
P4	12.30ab	12.42b
P7	12.06a	12.13a
P10	12.34b	12.50b
70°C	12.40b	12.29ab

Mean values with the same letter in the same column are not significantly different at 5% level.

Table 2. Color characteristics of the stored lentils.

Treatment	Color change							
	Robin lentils				Impact lentils			
	ΔL	Δa	Δb	ΔE	ΔL	Δa	Δb	ΔE
P4	-0.20d	0.17b	0.83c	0.86a	-1.86b	-0.08b	0.14b	1.86b
P7	-0.38c	0.73c	0.91d	1.23b	0.10d	0.71c	1.08c	1.30a
P10	-0.82b	0.71c	0.70b	1.29c	3.59d	-0.61a	1.03c	3.78c
70°C	-7.34a	-1.25a	-6.27a	9.73d	-8.07a	-0.63a	-4.92a	9.47d

Mean values with the same letter in the same column are not significantly different at 5% level.

Table 3. Dehulling characteristics of dried and original undried lentils after storage.

Treatment	Robin					
	Fines (%)	Hulls (%)	Undehulled (%)	Whole dehulled (%)	Split dehulled (%)	Dehulling efficiency (%)
Original	3.30	6.89	4.64ab	60.92d	22.21a	83.13b
P4	4.63	7.02	3.25a	21.35a	61.42d	82.77b
P7	4.89	6.80	2.08a	34.74b	49.57c	84.31b
P10	4.67	6.67	2.47a	40.34c	43.34b	83.67b
70^{o}C	4.82	6.63	7.57b	37.46b	40.23b	77.68a
	Impact					
Original	5.72	6.31	2.80b	45.70c	37.81a	83.50b
P4	5.32	6.64	2.86b	8.85ab	73.40c	82.25b
P7	5.12	6.76	1.89a	11.10b	72.43c	83.52b
P10	5.26	6.76	2.74ab	9.79b	73.19c	82.99b
70^{o}C	6.44	6.17	12.62c	6.53a	65.78b	72.31a

Mean values with the same letter in the same column are not significantly different at 5% level.

Table 4. Cohesiveness of the cooked lentils.

Treatment	Cooking time (min)			Cooking time (min)		
	2	3	4	2	3	4
	Cohesiveness of Robin lentils			Cohesiveness of Impact lentils		
Original	0.21a	0.25b	0.25b	0.23a	0.25a	0.27a
P4	0.19a	0.22a	0.22a	0.28a	0.25a	0.27a
P7	0.20a	0.21a	0.20a	0.25a	0.26a	0.23a
P10	0.19a	0.18a	0.20a	0.24a	0.26a	0.26a
70°C	0.24a	0.23a	0.24a	0.24a	0.24a	0.26a

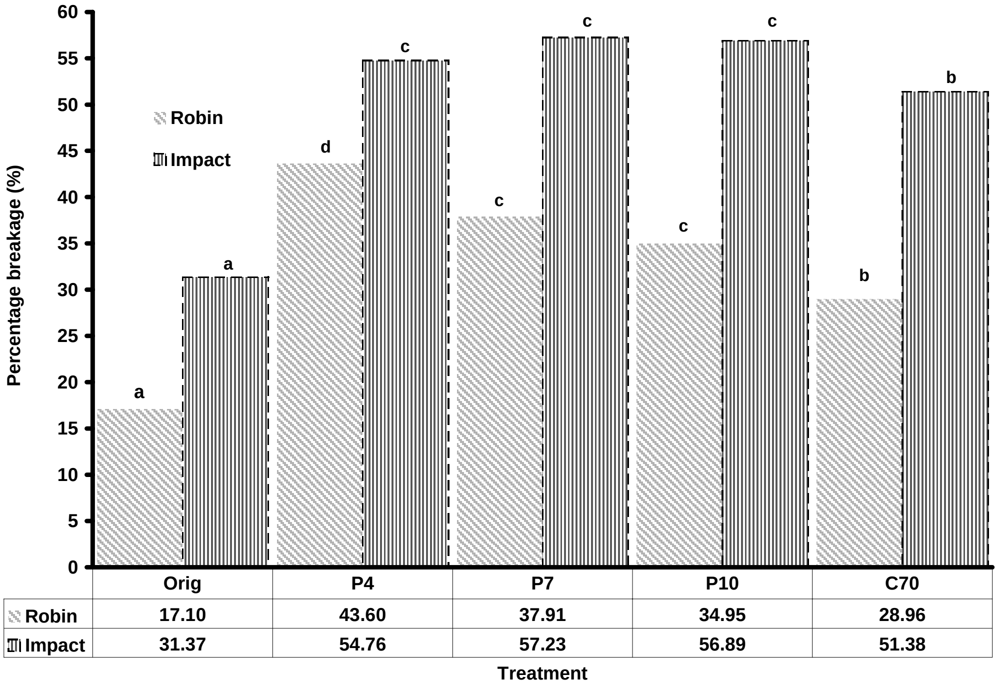
Mean values with the same letter in the same row are not significantly different at 5% level.

Table 5. Hardness of the cooked lentils.

Treatment	Cooking time (min)			Cooking time (min)		
	2	3	4	2	3	4
	Hardness of Robin lentils (N)			Hardness of Impact lentils (N)		
Original	6.38a (38.9)	6.60a (49.0)	5.38a (51.0)	7.99a (56.5)	6.68a (54.7)	6.25a (44.2)
P4	15.88a (41.3)	13.78a (43.4)	12.08a (43.2)	24.94a (34.1)	21.41a (37.8)	35.03b (32.0)
P7	16.01b (22.4)	14.54ab (36.0)	12.07a (22.4)	23.33a (24.9)	20.57a (17.8)	23.83a (18.8)
P10	14.33a (24.0)	12.44a (24.0)	12.66a (22.2)	24.73a (30.4)	21.95a (16.1)	20.88a (23.7)
70°C	7.50a (27.6)	7.01a (56.4)	6.54a (46.4)	17.50a (39.0)	15.36a (42.7)	16.01a (40.4)

Mean values with the same letter in the same row are not significantly different at 5% level.

Numbers in parenthesis are coefficient of variation (CV) in percentage (%).



	Orig	P4	P7	P10	C70
Robin	17.10	43.60	37.91	34.95	28.96
Impact	31.37	54.76	57.23	56.89	51.38

F
igure 1. Breakage susceptibility of dried and original non-dried lentils after storage. (Same letters on the same lentil variety are not significantly different at 5% level).