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Changes in physico-chemical quality characteristics of maize germ during storage

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Abstract
The present study was undertaken to see the effect of different packaging material on physico-chemical quality parameters of maize germ during storage. Maize germ is an enriched by product of starch processing industry and a copious source of oil of good quality. In the pursuance of the study, the germ was extracted at optimum parameter using laboratory size maize degermer machine (at PAU, Ludhiana). The germ was dried to the desired moisture content using mechanical drier and packed in LDPE, HDPE and plastic jar for 60 days under ambient conditions. Different quality parameters viz., color, moisture, fat, protein, fiber, free fatty acid (FFA) and titrable acidity (TA) were determined at regular interval of 15 days for 60 days of storage. Results showed that the maximum germ retained was on sieve size of 1.4 mm with 82.29% retention, average particle size of 1.85$\pm$.01 mm with uniformity index of 1.465: 8.514: 0.017. Statistical analysis showed that all the quality parameters increased significantly (P<0.05) with the increase in the storage period. Further, the moisture, fat, ash, FFA, Fiber increased significantly (P<0.05) whereas protein, fat, TA showed no significant difference (P<0.05) storage period for the combined effect of packaging material and storage period. It was observed that the maize germ stored in HDPE package was found best in quality followed by LDPE and Plastic jar.

Keywords: Maize germ, steeping, quality parameters, sieve analysis, packaging films, storage period

Introduction
Maize (*Zea mays*, L.) occupies a relevant place in the world economy and trade as an industrial grain crop (White and Johnson, 2003) [27]. Because of its diverse uses in the feed, industry and food sectors, maize is considered as an internationally important commodity driving world agriculture. Globally, it is grown in 184 M ha across 165 countries, with total production of 1016 MMT, and average productivity of 5.52 t/ha (FAOSTAT, 2014) [7]. It is preferred staple food for 900 million poor people, 120 -140 million poor farm families, and about one-third of all malnourished children globally (Murdia, *et al.*, 2016) [15]. By cultivating maize, farmers can save 90 per cent of water and 70 per cent of power as compared to paddy and earn far more than what they are earning through paddy and wheat (Anonymous, 2018) [2]. The maize kernel is indeed a wonderful gift of nature to mankind. It is composed of four main constituents' i.e germ, fibre (hull), gluten (proteinous material) and starch. Maize germ is used for producing flour, starch and corn oil (Payan, 2004) [18]. Maize germ, being valuable by-product of maize processing industry, constitutes 5-14% of the weight of kernel (Johnston *et al* 2005; MPOC 2008) [11]. It contains essential amino acids such as lysine (Mertz, 1972) [13]. Maize germ is suitable for oil extraction, its meal is suitable for corn germ flour production.

For the preparation of different products viz. flour, meal and grits from the maize it has to be degerminated to enhance the shelf life and improve the quality. Maize is generally processed by two distinct processes, namely wet milling and dry milling. In dry milling, the maize kernels are screened and tempered with hot water/ steam to loosen the germ and bran. The goal of wet milling is to separate maize into germ, starch, fiber and protein. Commercially corn kernels are steeped for about 48-50 h in SO_2 aqueous solution (50-55%) until the kernels have moisture content of at least 37% (Watson, 1991) [26].

Maize germ improves various properties such as dissolution vulnerability, water absorption, heat stability, gelatin production, emulsion stability and foam production (Messinger, *et al.*, 1987) [14]. Maize germ flour has many applications as a supplementary food because it contains high amounts of protein and useful mineral such as phosphorus, potassium, magnesium, sodium, calcium, iron, zinc and copper (Gardner, *et al.*, 1971) [9]. The water bonding capacity of maize germ is much higher than the ability of cheese and soyabean water absorption (Zayas and Lin, 1989) [28]. Due to higher range of protein in maize germ, the composition of essential amino acids is balanced, so that it can be used to compensate the shortage of amino acids in children nutrition (Siddiq, *et al.*, 2009a) [22]. Referring to numerous direct and indirect benefits from maize, storage study was undertaken to learn the shelf life of maize germ extracted from whole maize kernel.

Materials and Methods
The maize kernels of variety PMH 1 were obtained from Punjab Agricultural University farm. The maize kernels, having 96% purity were selected for the study. Maize germ was separated by Maize degermer designed and developed at Department of Processing and Food Engineering, Punjab Agricultural University, Ludhiana. The germ was dried in a tray drier dryer at 60ºC until, the moisture content of germ reached up to 4% (wb) and the different engineering properties viz., length, width, geometric mean diameter, sphericity, roundness, surface area, bulk density etc. of maize germ was determined using standard methods. The maize germ was packed in different packaging material i.e. high density polyethylene HDPE of thickness 37.5 µm (150 gauge), low density polyethylene LDPE of thickness 51 µm (200 gauge) and in plastic jars for 60 days under ambient conditions. The average temperature and humidity during the month of storage (February and March) were 20-25ºC and 60-65%. Different quality parameters of maize germ: moisture content, color, fat content, protein content, free fatty acid content, fiber content, titrable acidity content and ash content were determined at regular interval of 15 days using standard methods as discussed under:

Protein content
Protein content was determined by available nitrogen in the sample by Micro Kjeldhal method (AOAC, 2000) [1]. The protein content was estimated using following equation:

$$N_2 = \frac{(\text{blank titre} - \text{sample titre}) \times \text{Normality of HCl} \times 14 \times 100}{\text{weight of sample taken} \times 1000}$$

And Protein (%) = 6.25×Nitrogen (N_2) content (%).

Crude fat content
Moisture free 5 g sample was taken in readymade thimble and oil was extracted in a pre weighed beaker using petroleum ether in Soxhlet apparatus for 2.5 to 3 hours and the crude fat content of sample was estimated by (AOAC, 2000) [1]. The following equation was used for estimation of crude fat content (%).

$$\text{Crude fat (\%)} = \frac{\text{weight of fat(g)} \times 100}{\text{weight of sample}}$$

Crude fiber content
Three grams of moisture and fat free sample was first digested with 150 ml boiling 0.255N H_2SO_4 for 30 min. The crude fiber content of sample was calculated by using the following equation

$$\text{Crude fiber} = \frac{\text{We} - \text{Wa}}{\text{W}} \times 100$$

Where, We = Weight of the sample after overnight drying in crucible
Wa = Weight of the sample after crucible heating in muffle furnace
W = Total weight of the sample

Ash content
About 5g of samples were taken in crucibles. These were burnt on the hot plate and then placed in an electric muffle furnace at 600 °C for 6 hours as shown (AOAC, 2000) [1].
The following formula was used to calculate the ash content percentage

$$\text{Ash content (\%)} = \frac{\text{Weight of ash (g)}}{\text{Weight of sample (g)}} \times 100$$

Color measurement
Color properties of maize germ were measured using Color Reader (CR - 10). The color was described by a value of 'L', 'a' and 'b', where L indicates intensity of color i.e. lightness which varies from L=100 for perfect white to L=0 for perfect black and 'a' and 'b' are chromaticity dimensions which give understandable designations of color i.e. the value of 'a' measured redness when positive, grey when zero and blueness when negative. The color change was calculated from 'L', 'a' and 'b' readings as suggested by

$$\text{Colorchange } (\Delta E) = \sqrt{[(L - L_0)^2 + (b - b_0)^2 + (a - a_0)^2]}$$

Titrable acidity
Titrable acidity of reconstituted sample was estimated by diluting the aliquot of the sample with water to a fixed volume and then titrated with 0.1 N NaOH using phenolphthalein as an indicator. % acidity was calculated as the % age of anhydrous citric acid using;

$$\text{Total acid (\%)} = \frac{\text{Titre} \times \text{Normality of alkali} \times \text{Volume made up} \times \text{eq. weight of acid} \times 100}{\text{Vol of sample taken for estimation} \times \text{weight or vol of sample taken} \times 1000}$$

Texture profile analysis
Texture profile analysis of maize germ was carried out to find hardness. The Instron, TA-XT2 texture analyzer machine was used to perform a compression test (Bourne 1968, 1974). The texture analyser (TA-Hadi, Plate) having automatic loading rate and chart plotting facility was used to determine texture profile analysis, pre-test speed – 5mm/s, test speed 0.5mm/s, post test speed – 10mm/s, strain – 90%, trigger type – auto - 3g and data acquisition rate 400pps, 250 kg load cell and 75mm cylinder probe(P/75) was used for this determination.

Flavour/Odour
The flavour/ Odour were carried out to find out the property of the maize germ. It was done using the sense organs of smell.

Statistical Analysis
The data obtained from the experiments were analyzed using the technique of analysis of variance (Panse and Sukhatme, 1985) [17]. The data were analyzed for significance at ($P \leq 0.05$) using SPSS 20.0.

Results and Discussion

Engineering properties of maize germ

The maize germ was separated by the developed maize degermer machine (Sharma, S. *et al.*, 2017; Sharma, S. *et al.*, 2018) [20, 21]. The different engineering properties of maize germ were presented in Table 1. It was observed from the table that at the moisture content of 4%, the bulk density, true density, angle of repose, porosity and thousand grain weight of germ obtained were 388.84 kg/m³, 698.46 kg/m³, 26.87º, 45.36 and 33.43 g respectively**.**

Table 1: Different engineering properties of maize germ

S No.	Engineering property	Maize germ
1.	Moisture content (%wb)	4 ±0.03
2	Length (mm)	8.01±0.52
3.	Width (mm)	4.34±0.61
4.	Thickness (mm)	2.98±0.50
5.	Geometric mean diameter (mm)	4.69±0.58
6.	Arithmetic mean diameter (mm)	5.11±0.53
7.	Sphericity	0.58±0.04
8.	Roundness	0.49±0.04
9.	Surface area (mm²)	69.89±17.19
10.	Volume (mm³)	55.77±20.42
11.	Bulk density (kg/m³)	388.84±1.36
12.	True density (kg/m³)	698.46±13.46
13.	Porosity	45.36±1.04
14.	Thousand grain weight (g)	33.43±0.31
15.	Coefficient of internal friction	0.53±0.01
16.	coefficient of external friction	0.45±0.01
17.	Angle of repose	26.87±1.44

Effect of Packaging Materials on Physico-chemical Properties of Maize Germ during storage

The effect of packaging materials on different physico-chemical properties viz. color, moisture content, fat content, ash content, crude fibre content, protein content, free fatty acids were determined at regular interval of 15 days for 60 days during the storage period. The effect of each parameter is explained under;

Moisture content

Moisture content of maize germ is very important for its shelf life, lower the germ moisture, the better is its storage stability (Butt, *et al.*, 2004) [5]. The variation in moisture content of maize germ with respect to storage period in different packaging material was shown in Fig.1. The moisture content of germ increased from 4.00 to 7.00% after 60 days of storage period. The increase in moisture content irrespective of packaging materials may be attributed due to hygroscopic properties of germ. Analysis of variance showing the effect of process variables on different quality parameters of maize germ was presented in Table 2, 3, 4. The effect of packaging material, storage period and the combination of both was statistically significant at 5% level of significance. The maximum increase in moisture content was observed in Plastic jar i.e. 7.00% closely followed by LDPE (6.68%) and minimum in HDPE (4.88%). HDPE was observed to be the best packaging material than LDPE and Plastic jar due to low water vapor transmission properties.

Table 2. Analysis of variance for effect of process variables on quality parameters of maize germ

	F- Value						
	Moisture content	**Fat content**	**Ash content**	**Protein content**	**Free fatty acid**	**Fiber content**	**Titrable acidity**
Individual effect							
Packaging material	174.87*	11.99*	108.12*	0.274NS	92.53*	12.16*	2.37NS
Storage days	460.07*	69.25*	447.46*	25.88*	259.77*	93.07*	115.31*
Combined effect							
Packaging material x storage days	41.61*	2.19NS	10.07*	0.09NS	34.38*	4.05*	0.34NS

*Significant at 5% level; NS = Not significant

Table 3: Effect of packaging material on proximate composition packaging material

Packaging Material	Moisture (%)	Fat (%)	FFA (%)	Ash (%)	Protein (%)	Fiber (%)	Titrable Acidity (%)
LDPE	4.99b	40.54a	1.61b	2.99b	11.60a	5.65a	0.06a
HDPE	4.35c	41.05a	1.57c	2.70c	11.63a	5.67a	0.06a
Plastic Jar	5.11a	39.00b	1.69a	3.23a	11.56a	5.59b	0.05a

Values with different letters (a,b,c) differ significantly ($P<0.05$)

Table 4: Effect of storage days on proximate composition packaging material

Storage Days	Moisture (%)	Fat (%)	FFA (%)	Ash (%)	Protein (%)	Fiber (%)	Titrable Acidity (%)
0	4.00a	44.58a	1.52d	1.96e	11.95a	5.78a	0.03d
15	4.26b	41.97b	1.54c	2.71d	11.87b	5.74a	0.03d
30	4.57c	40.45b	1.57c	3.08c	11.72a	5.72a	0.06d
45	5.07b	37.59c	1.66b	3.37b	11.58b	5.52b	0.07b
60	6.18a	36.39c	1.82a	3.76a	10.88c	5.42c	0.08a

Values with different letters (a,b,c) differ significantly ($P<0.05$)

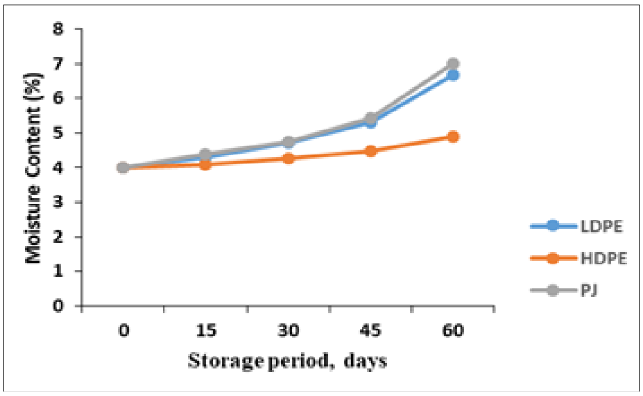

Fig 1: Effect of packaging material on moisture content of maize germ during storage Color

Variation in color of dried maize germ after 60 days of storage in different packaging material was presented in Table 3. It was observed that the color "L", "a" and "b" value of germ decreased with the increase in storage period in all the packaging material i.e. LDPE, HDPE and Plastic jar. The color of the germ obtained was light brown due to positive value of "a" indicating redness. The overall change color was more pronounced in plastic jar i.e. 3.88 followed by LDPE (2.37) and minimum in HDPE (1.14).

Table 3: Effect of packaging material on color of maize germ during storage

Packaging Material	0th day			30th day			60th day			ΔE
	L	a	b	L	a	b	L	a	b	
LDPE	67.3	+1.4	+23.1	61.4	+1.2	+21.8	65.4	+0.8	+21.8	2.37
HDPE	67.3	+1.4	+23.1	64.8	+1.0	+22.4	66.7	+0.3	+21.9	1.14
Plastic jar	67.3	+1.4	+23.1	62.8	+0.7	+20.6	64.8	+0.4	+20.3	3.88

Fat content

Fat is the major constituent of maize germ. It was observed from Fig. 2 that there was decrease in fat content with the increase in the storage period irrespective of packaging material i.e. LDPE, HDPE and Plastic jar. ANOVA given in Table 2,3,4 reveals that the packaging material and storage period had a significant effect on fat content ($p<0.05$) but non-significant difference was observed amongst the interaction between packaging material and storage period at 5% level of significance. The maximum decrease in fat content was observed in Plastic jar (33.70%) and minimum in HDPE (38.50%). The decrease may be attributed to the lipolytic activity of enzymes i.e. lipase and lipoxidase (Murugkar and Jha 2011) [16].

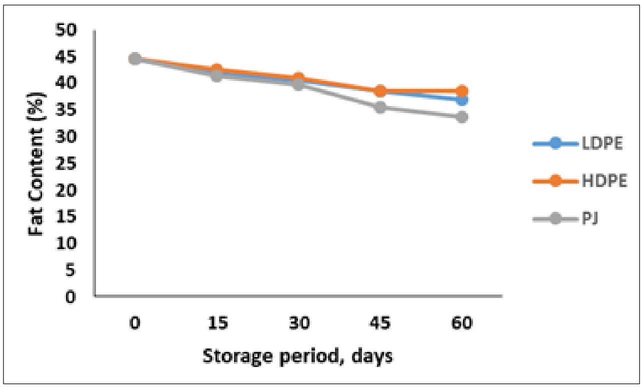

Fig 2: Effect of packaging material on fat content of maize germ during storage

Ash content

The variation in ash content of maize germ in different packaging material during storage was presented in Fig. 3. It was observed from the figure that depicted that the ash content of maize germ increased with storage period in all the packaging material. The ash content varied between 3.32% and 4.04% for LDPE, HDPE and Plastic jar respectively. Significant difference in ash content was observed due to packaging material, storage period and it's combination at 5% level of significance (Table 2,3,4) which was agreed with Upadhyay *et al* (1994) [25]; Butt *et al* (2004) [5]. The maximum value of ash content was observed in LDPE and Plastic jar i.e. 4.04%, followed by HDPE (3.32%). The results were comparable to those reported by Baldini, *et al.* (1982) [3].

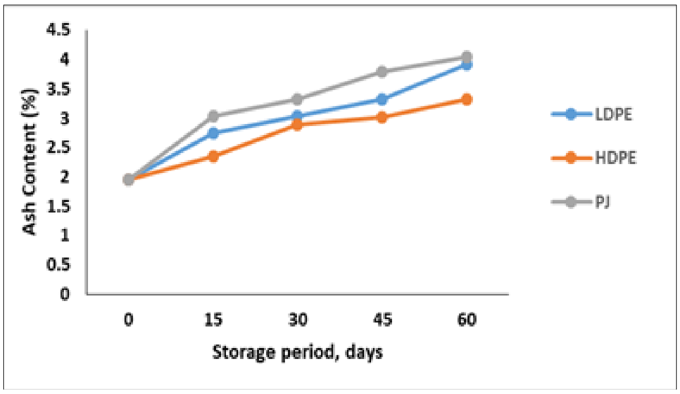

Fig 3: Effect of packaging material on ash content of maize germ during storage

Protein content

A marginal drop in protein content was observed during storage of maize germ as showed in Fig. 4. ANOVA in Table 2,3,4 depicted that there was slight decrease in the protein when stored up to 60 days period whereas no significant difference was observed between the packaging materials viz., HDPE, LDPE and Plastic jar at 5% level of significance. Initial protein content obtained at 0 day period was observed to be 11.95% which was decreased to 10.96, 10.76 and 10.92% in HDPE, plastic jar and LDPE respectively after 60 days of storage period. Results obtained were agreed with Baldini *et al* (1982) [3].

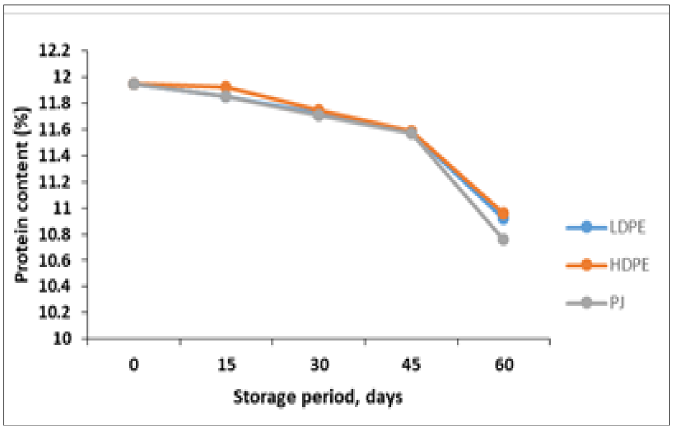

Fig 4: Effect of packaging material on protein content of maize germ during storage

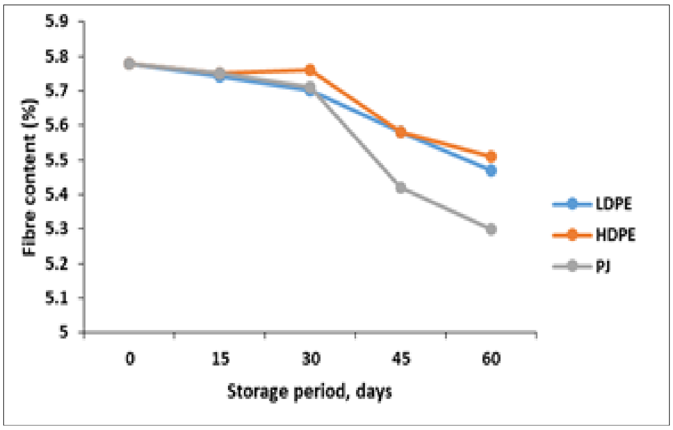

Fig 6: Effect of packaging material on fiber content of maize germ during storage

Free fatty acid content

Changes in the free fatty acid content of germ during storage were presented in Fig. 5. It was noted that marginal increase in free fatty acid was observed during storage. From Table 2,3,4, it was observed that free fatty acid content was marginally increased with the increase in storage period showing significant difference at 5% level of significance. Initial FFA content was observed to be 1.5% which was increased to 1.68, 2.04 and 1.75% in HDPE, Plastic jar and LDPE respectively after 60 days of storage period. Similar results were reported for wheat germ by Srivastava, *et al.*, (2007) [24].

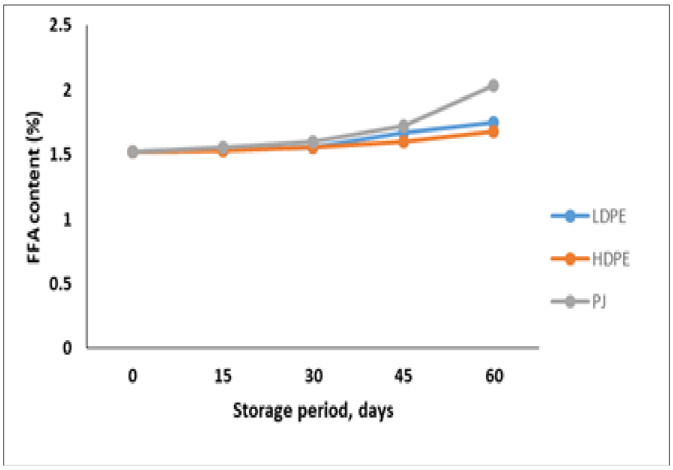

Fig 5: Effect of packaging material on free fatty acid content of maize germ during storage

Fiber content

Figure 6 depicted that fiber content of maize germ decreased with storage period. ANOVA in Table 2, 3, 4, showed no significant difference between the packaging materials viz., HDPE, and LDPE from 5.47 to 5.51% during 60 days of storage period at 5% level of significance. Comparatively, HDPE showed minimum decrease in fiber content from 5.78 to 5.51% followed by LDPE from 5.78 to 5.47% and then plastic jar from 5.78 to 5.30%. The results are comparable with the storage study done on millet flour (Sidhu, G. *et al.*, 2016) [23].

Titrable acidity

Figure 7 depicted that titrable acidity slightly increased with the increase in the storage days. From Table 2, 3, 4, it can be observed that there was no significant difference between the packaging materials viz., HDPE, LDPE and Plastic jar while significant difference can be observed after 15 days of storage period at 5% level of significance. The maximum value of titrable acidity was obtained for LDPE and Plastic jar i.e. 0.09% while minimum for HDPE (0.08%). Similar results were given by (Hruskova and Machova, 2002) [10] for wheat flour.

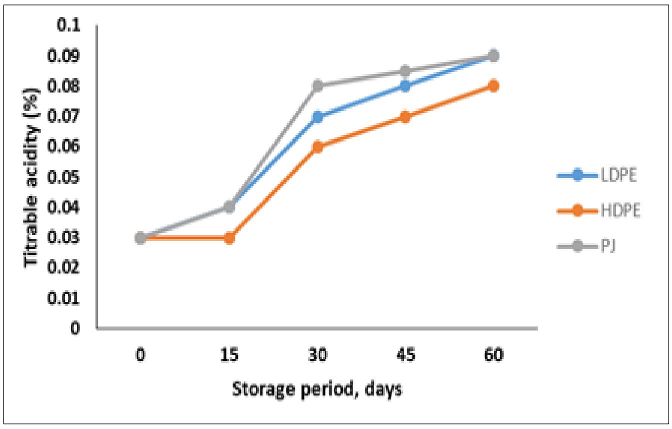

Fig 7: Effect of packaging material on titrable acidity content of maize germ during storage

Texture profile of maize germ

The hardness of maize germ was checked before and after drying. The texture analyzer machine was used to determine the hardness of germ. The initial force of 195.212 $\pm$ 3.5 N was used at a distance of 4.998 mm for 2.5 second for maize germ with 50% moisture content. The value of force increased 492.730 N $\pm$ 4.6 N at a distance of 5 mm for 2.5 seconds when moisture content of maize germ was dried up to 4% moisture content. This may be due to the decrease in moisture content due to which greater force is required for the determination of hardness parameter. Similar results were showed by Siddiq, *et al.*, (2009a) [22] who reported that textural properties (hardness and stickiness) of wheat flour blends with defatted maize germ flour (DMGF) increased with storage period.

Sensory evaluation of maize germ

Oxidation constitutes a major factor for quality deterioration of any food product. The rate of oxidation depends on a number of factors including the availability of oxygen, presence of light and temperature etc. The odour of maize germ stored in different packaging material remained constant at storage interval of 60 days because of its quality characteristics remained constant during storage time. Similar results were determined by Chiacchierini, *et al.*, (2007) [6] for olive oil.

Conclusions

Overall it can be concluded from the study that the stored germ showed significant effect on physico-chemical properties when packed in different packaging material for 60 days, (p<0.05) at 5% level of significance. However, the odour of maize germ remained constant at storage interval of 60 days. Also, the storage in HDPE package for six months showed best result without deterioration in quality parameters. The outcome is likely to be useful for any oil industry, as this germ storage study shall give them overview of shelf life i.e. for the time they could keep the extracted germ for further processing.

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