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Biochemical Properties of Whole and Degermed Maize Flours during Storage

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Abstract An attempt was made to study the effect of packaging materials and storage periods on biochemical qualities of whole and degermed maize flours. The flours were packed in three packaging materials viz. aluminium laminated foil (ALF), high density polyethylene (HDPE) and low density polyethylene (LDPE) and its biochemical qualities were determined at ten days storage interval for 70 days storage. It was found that degermed maize flour is better in terms of moisture, protein, fat, FFA, total acidity, ash and textural properties as compared to the whole maize flour. The moisture, fat and FFA were increased whereas protein, total acid and ash contents decreased with increase in storage interval. Maize flour stored in aluminium foil found best followed by HDPE. Biochemical qualities of degermed maize flour showed that it can be stored for longer period as compared to whole maize flour.

Keywords Whole Maize Flour, Degermed Maize Flour, Biochemical Qualities,Textural Properties

1. Introduction

Maize or corn (*Zea mays Linn.*) is one of the most versatile cereal crops of the world. It is an important cereal crop, serving as staple food to large population of Africa, Asia and North and South America. It can be processed into different breakfast items, food and feed ingredients and beverages for its consumption throughout the world (Chakraverty, 1988; Rajoo, 1998). Many people throughout the world, particularly living in Asia or people of Asiatic origin, make their own dough-based products on a daily basis. There are five general classes of corn e.g. flint corn, popcorn, flour corn, dent corn, and sweet corn (Watson, 1987a). Different types of corn have different proportions of horny and floury endosperm. The floury endosperm is softer and easier to break than the horny endosperm (Jamin & Flores, 1998). Different parts of corn have different physical and chemical properties. Yellow corn has a horny endosperm and more carotenoids (74–86%), which are the source of yellow color in corn (Watson, 1987b). Hardness and breakage susceptibility are related properties that can affect the utilization of corn (Pomeranz *et al.,* 1984).

Maize germ constitutes 5-14% of the weight of kernel and is a good source of key nutrients especially 18-41% of oil (Johnston *et al.,*2005; MPOC, 2008). Edible oils are vital, serving as important ingredient of many foods by imparting characteristic flavor and texture to finished food products (Rudan-Tasic & Klofutar, 1999). Chemical and physical properties of edible oils are imperative as they tie up with processing functionality, storage stability and nutritional behavior. In India, maize has become the third important food grain after wheat and rice. About 35% of the harvested corn is used as a direct food, usually in the form of unleavened bread (*chapattis*) though consumption in other forms (maize-on the-cob, as maize kernels) has also increased (Sandhu *et al.,* 2007).*Chapatti* is most often in the form of round substantially flat pieces of dough, which are appropriately cooked/ baked. *Chapatti* is the staple diet of a majority of people living in the Indian subcontinent. Corn flour is used to make *chapattis*, which are eaten commonly in most part of India. By and large, corn breads are more commonly consumed by the less affluent people (Mehta & Dais, 1999). Sinha and Sharada (1992) compared the *chapatti*-making properties of corn flours, before and after alkali treatment, and reported that untreated *chapattis* were more acceptable than treated ones. The desired quality parameters in *chapatti* are greater pliability, soft texture, light creamish brown colour, slight chewiness and baked aroma, which is usually prepared from flour (Rao *et al.,* 1986). In many instances it is a sign of good housewife that all the dough products that she makes are of precisely the same diameter and uniform thickness, having perfect circularity and taste. This, of course, involves a considerable amount of skill, and also occupies a considerable amount of time, since it is difficult to roll a perfectly circular dough element from a portion of dough. The taste of *chapatti* depends on the quality of flour used.

The present work was carried out to study the bio-chemical qualities of whole and degermed maize flours

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stored in three packaging materials viz. aluminium laminated foil (ALF), high density polyethylene (HDPE) and low density polyethylene (LDPE) during storage.

2. Material and Methods

A bold variety of Maize (var. *Jai Kisan*), commonly grown in Karnataka state of India, was procured from the local market of Ludhiana, India for the present study. The maize kernels were cleaned by using pedal cum power operated grain cleaner (top sieve: 8.0 mm Φ; bottom sieve: 2.0 mm × 2.5 mm) to remove foreign matter such as dust, dirt, chaff, immature and broken grains. The experiments on different bio-chemical qualities of whole and degermed maize flours were conducted at Central Institute of Post-Harvest Engineering and Technology, Ludhiana (India).

2.1. Sample Preparation

Maize procured from local market was divided into two parts. The first part of whole maize was ground to make powder using burr mill whereas second part of maize was processed through CIPHET maize degermer to separate the maize grit and maize germ. Degermed maize grit was ground to make powder using burr mill and sieved for uniform particle size using ordinary household sieve. Whole maize and degermed maize flours were packed in triplicate in three packaging materials (ALF, HDPE and LDPE) for 70 days storage period with 10 days storage interval. For determination of biochemical qualities, separate packet foreach storage interval were used and discarded after each storage studies.

2.2. Determination of Bio-Chemical Qualities

2.2.1. Moisture Content

The moisture contents of the samples were determined using Kern Moisture Analyzer (Model: KERN, MLB 50-3N, Kern & Sohn GmbH, D- 72336 Balingen, Germany).

2.2.2. Protein

Protein content was determined by available nitrogen in the sample by Micro Kjeldhal method (AOAC, 1980). One gram sample was digested in 20 ml of sulphuric acid (H_2SO_4) at 420°C using copper sulphate and potassium sulphate as catalyst mixture. Digested sample was distilled using 40% NaOH in KjelTech (Pelican equipment Limited, Chennai, India). Ammonia was absorbed in excess of 4% boric acid solution and then titrated with standard acid (0.1N HCl) to estimate the protein content. The protein content was estimated using following equation:

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

and, $\text{Protein}\ (\%) = 6.25 \times \text{Nitrogen}\ (N_2)\text{content}\ (\%)$

2.2.3. Crude Fat

Moisture free 5 g sample was taken in readymade thimble and oil was extracted in a pre-weighed beaker using petroleum ether in SOCS PLUS (Pelican Equipment Limited, Chennai, India) for 2.5 to 3 hours. The beaker was then dried in a hot air oven to evaporate petroleum ether. Final weight of the beaker was taken and used for the estimation of crude fat content of sample (AOAC, 1980). The following equation was used for estimation of crude fat content (%) in the sample:

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

2.2.4. Free Fatty Acids (FFA)

The FFA was determined by using the procedure, given by Thapar*et al.*(1988). One gram of flour sample was added in 50 ml of petroleum ether and stirred for 1 hour before filtering the mixture followed by 2 more washing with 5 ml of petroleum ether. Final reaction mixture was evaporated at very low temperature. 25 ml of ethanol and benzene (3:1) solution was added in it and 10 ml from the above-prepared solution was taken in a separate flask and titrated against standard alkali with addition of one to two drops of pH indicator. The FFA (%) was determined by using following equation:

$$\text{FFA} = \frac{\text{ml of alkali used} \times \text{Normality of alkali} \times \text{molecular weight of oleic acid}}{\text{weight of sample (g)}}$$

$$\%\ \text{FFA} = \left(\frac{\text{volume of NaOH} \times \text{Normality of NaOH} \times 282.46(\text{Moles of oleic acid})}{\text{weight of sample or oil} \times 1000}\right) \times 100$$

2.2.5. Titratable Acidity

Titratable acidity of reconstituted sample was estimated by diluting the aliquot of the sample with water to a fixed volume and then titrated with 0.1N NaOH using phenolphthalein as an indicator. Percentage acidity was calculated as the percentage of anhydrous citric acid using following formula (Kadam *et al.,* 2010):

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

2.2.6. Ash

Samples (5 g) are taken in triplicate in crucibles. These were burnt on hot plate and then placed in an electric muffle furnace at 600° C for 6 hours. After cooling the crucibles to room temperature, the residue left (ash) in the crucible was weighed (AOAC, 1980). The following formula was used to calculate the ash (%):

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

2.3. Textural Properties

Based on preliminary experiments, optimized known quantity of maize flour was mixed with known quantity of water i.e. 50: 20 w/w (maize flour: water) and kneading was done manually in triplicate. Textural profile analysis (TPA) of maize flour dough balls were carried out using texture analyzer (TA-Hdi, Stable Micro system, UK). The cutting probe Blade with knife (HDP/BSK) with test speed of 1.00mm/s, distance of 20.0mm and trigger force of 0.10N was used and puncture probes P2N needle was operated at testspeed of 1.00mm/s, distance of 10.0mm and trigger force of 0.10N for the textural properties of the whole and degermed maize flour dough balls. The textural behavior such as cutting force, distance, time, area and stickiness were determined for both whole and degermed maize flour dough balls.

2.4. Statistical Analysis

The experiments were carried out in triplicate for all the parameters at each storage interval throughout the storage period of 70 days. Data were analyzed as per one/ two factor analysis of variance (ANOVA) using LSD of AgRes statistical software package.

3. Results and Discussions

3.1. Moisture Content

Moisture content of flour is very important for its shelf life, lower the flour moisture, the better its storage stability (Butt *et al.,*2004). The storage days and packaging material are highly significant at P<0.05. It was found that moisture content in stored product increased with increasing storage period. Minimum moisture was up to 30 days and then it has shown increasing trend. Hruškova and Machova (2002) observed that the changes in the moisture contents depended on the short time storage conditions and had a different time course in the individual locations. ALF packed degermed maize flour was found best with less moisture as compared to the whole maize flour. Butt *et al.* (2004) also reported that the moisture content was affected significantly due to storage, treatments, packaging and their interaction.

3.2. Protein

The protein content in both degermed maize and whole maize flours were decreased with increased in storage interval and significant difference was observed at P<0.05. These are in accordance with Butt *et al.* (2004) who reported that the crude protein content showed a decreasing trend with storage of wheat flour. The Mean Comparison by LSD (Descending order) shows that maximum protein was retained in whole maize flour packed in ALF and HDPE. It may be due to the presence of germ in the flour which might have contributed in total quantity (Siddiq*et al*., 2009). The mean protein content in degermed and whole maize flour ranged from 7.22 to 8.28% and 7.86 to 8.54%, respectively. From Table 1, it's clear that storage days and packaging material are highly significant at P<0.05 and interaction between storage period and packaging materials are highly significant. The maximum protein content was found during initial storage period in aluminium foil followed by HDPE.

Table 1. Analysis of variance for protein content of whole and degermed maize flours during storage.

Source	df	SS	MS	F	PROB
TOT	143	88.03	0.6156	255.6577	
Trt	47	87.80	1.8681	775.8095	0.298 NS
Err	96	0.23	0.0024	1.0000	
d	7	11.94	1.7057	708.3892	0.000 **
p	5	30.78	6.1562	2556.5752	0.000 **
dp	35	45.08	1.2880	534.8985	0.000 **
Err	96	0.23	0.0024	1.0000	
	SED	CD(0.05)	CD(0.01)		
d	0.0163	0.0324	0.0429		
p	0.0141	0.0281	0.0372		
dp	0.0400	0.0795	0.1053		
CV	0.61%				

3.3. Fat

The fat content in both degermed maize and whole maize flours were increased with increase in storage interval. The Mean Comparison by LSD (Descending order) shows that minimum fat content was in degermed maize flour packed in ALF and LDPE. It may be due to the removal of germ from maize prior to flour making. The main component responsible for fat in maize is germ, which is responsible for fat content in it. It's clear that storage days and packaging material are highly significant at P<0.05 and interaction between storage period and packaging materials are highly significant (Table 2). The maximum fat content was found in whole maize flour, which was not desirable from storage point of view.

3.4. FFA

The FFA content in both degermed maize and whole maize flours were increased with increase in storage interval as expected (Table 3). The Mean Comparison by LSD (Ascending order) shows that minimum FFA was present in degermed maize flour packed in ALF and HDPE. It may be due the separation of germ from maize prior to making flour. The main component in maize is germ, which is responsible for fat and FFA content in it. Higher lipolytic and proteolytic activities lead to loss in nutrients (protein and fat) and production of more FFA resulting in inferior sensory characteristics (Butt et al., 2004). The minimum FFA was observed in degermed maize flour packed in ALF, which is a determinant factor for safe storage and consumption.

3.5. Total Acid

The total acid percent content decreased with increase in storage interval for both degermed maize and whole maize flours. It is also reported that the acidity of commercial wheat flour was significantly increased with time regard less of the storage locations (Hruškova & Machova, 2002). The Mean Comparison by LSD (Descending order) shows that whole maize flour had maximum total acid percentage as compared to the degermed maize flour. From Table 4, it is clear that the treatments are non significant but the packaging material and storage days and its interactions are highly significant at P<0.05 and CV is 9.09%.

Table 2. Analysis of variance for fat content of whole and degermed maize flours during storage.

Source	df	SS	MS	F	PROB
TOT	143	280.57	1.9620	601.13	
Trt	47	280.25	5.9629	1826.94	0.813 NS
Err	96	0.31	0.0032	1.00	
d	7	46.11	6.5884	2018.60	0.000 **
p	5	217.41	43.4824	13322.27	0.000 **
dp	35	16. 72	0.4779	146.43	0.000 **
Err	96	0.31	0.0032	1.00	
	SED	CD(0.05)	CD(0.01)		
d	0.0190	0.0378	0.0500		
p	0.0164	0.0327	0.0433		
dp	0.0466	0.0925	0.1225		
CV	1.64%				

Table 3. Analysis of variance for FFA of whole and degermed maize flours during storage.

Source	df	SS	MS	F	PROB
TOT	143	92.33	0.6456	1852.19	
Trt	47	92.30	1.9638	5633.35	0.434 NS
Err	96	0.03	0.0003	1.00	
d	7	57.95	8.2793	23749.54	0.000 **
p	5	25.57	5.1148	14672.19	0.000 **
dp	35	8.77	0.2506	718.85	0.000 **
Err	96	0.03	0.0003	1.00	
	SED	CD(0.05)	CD(0.01)		
d	0.0062	0.0123	0.0163		
p	0.0053	0.0107	0.0141		
dp	0.0152	0.0302	0.0400		
CV	1.63%				

3.6. Ash

The ash content decreased with increase in storage interval for both degermed maize and whole maize flours, as expected. The Mean comparison by LSD (Ascending order) shows that the presence of ash content was less in all the samples during 70days of storage period. Ash content increase was very less in degermed maize flour as compare to the whole maize flourpacked irrespective of packagingmaterial used. From Table 5, it's clear that storage days and packaging material are highly significant at P<0.05 and interaction between storage period and packaging materials are highly significant. The minimum ash content was found in all packaging materials stored up to 70 days of interval.

Table 4. Analysis of variance for total acid (%) of whole and degermed maize flours during storage.

Source	df	SS	MS	F	PROB
TOT	143	1.74	0.0122	67.78	
Trt	47	1.73	0.0368	204.18	0.260 NS
Err	96	0.01	0.0001	1.00	
d	7	1.41	0.2014	1117.22	0.000 **
p	5	0.16	0.0337	187.22	0.000 **
dp	35	0.15	0.0043	24.00	0.000 **
Err	96	0.01	0.0001	1.00	
	SED	CD(0.05)	CD(0.01)		
d	0.0044	0.0088	0.0117		
p	0.0038	0.0076	0.0101		
dp	0.0109	0.0217	0.0288		
CV	9.09%				

Table 5. Analysis of variance for Ash content (%) of whole and degermed maize flours during storage.

Source	df	SS	MS	F	PROB
TOT	143	12.74	0.0891	67.24	
Trt	47	12.61	0.2684	202.56	0.247 NS
Err	96	0.12	0.0013	1.00	
d	7	0.97	0.1398	105.55	0.000**
p	5	10.27	2.0554	1551.28	0.000 **
dp	35	1.35	0.0388	29.29	0.000 **
Err	96	0.12	0.0013	1.00	
	SED	CD(0.05)	CD(0.01)		
d	0.0121	0.0240	0.0318		
p	0.0105	0.0208	0.0276		
dp	0.0297	0.0590	0.0781		
CV	3.51%				

3.7. Textural Properties of Whole and Degermed Maize Flour Dough

The ANOVA of textural properties of the whole and degermed maize flour dough balls are presented in Tables 6and 7, respectively. The Mean Comparison by LSD (Descending order) shows that the textural properties of the dough increased with increasing storage period and highly significant at P<0.05 (Tables 6 & 7). Siddiq *et al.* (2009) reported that textural properties (hardness and stickiness) of wheat flour blends with defatted maize germ flour (DMGF) increased with storage and the increase in stickiness is probably due to the low oil content of DMGF, and due to increased inter-particle friction. Rehydration time of 10 to 20 minute gave the best dough for cutting property, which is more suitable for making *chapatti*. The better results were observed for 40 days storage and 20 minutes rehydration time. The CV value is less in degermed maize flour dough as compared to the whole maize flour dough. The comparison between storage days and rehydration time is significant for degermed maize dough and other interaction shown non-significant.

Table 6. Analysis of variance for textural properties of whole maize flour dough during storage.

Source	df	SS	MS	F	PROB
TOT	349	3411.44	9.7749	5.1559	
Trt	174	3079.66	17.6992	9.3356	0.000 **
Err	175	331.78	1.8958	1.0000	
d	6	1765.86	294.3110	155.2366	0.000 **
t	4	56.41	14.1026	7.4385	0.000 **
c	4	25.79	6.4487	3.4015	0.010 **
dt	24	1016.94	42.3726	22.3498	0.000 **
tc	16	21.23	1.3272	0.7001	0.792 NS
dc	24	37.64	1.5684	0.8273	0.699 NS
dtc	96	155.76	1.6225	0.8558	0.800 NS
Err	175	331.78	1.8958	1.0000	
	SED	CD(0.05)	CD(0.01)		
d	0.2753	0.5435	0.7171		
t	0.2327	0.4593	0.6061		
c	0.2327	0.4593	0.6061		
dt	0.6157	1.2153	1.6036		
tc	0.5204	1.0271	1.3553		
dc	0.6157	1.2153	1.6036		
dtc	1.3769	2.7175	3.5858		
CV	34.26%				

Table 7. Analysis of variance for textural properties of degermed maize flour dough during storage.

Source	df	SS	MS	F	PROB
TOT	349	2749.51	7.8782	7.0701	
Trt	174	2554.51	14.6811	13.1751	0.000 **
Err	175	195.00	1.1143	1.0000	
d	6	1548.67	258.1121	231.6344	0.000 **
t	4	90.28	22.5708	20.2555	0.000 **
c	4	1.44	0.3620	0.3249	0.861 NS
dt	24	790.77	32.9490	29.5691	0.000 **
tc	16	7.45	0.4657	0.4180	0.977 NS
dc	24	20.33	0.8473	0.7605	0.782 NS
dtc	96	95.54	0.9952	0.8931	0.728 NS
Err	175	195.00	1.1143	1.0000	
	SED	CD(0.05)	CD(0.01)		
d	0.2111	0.4166	0.5498		
t	0.1784	0.3521	0.4646		
c	0.1784	0.3521	0.4646		
dt	0.4720	0.9317	1.2294		
tc	0.3989	0.7874	1.0390		
dc	0.4720	0.9317	1.2294		
dtc	1.0556	2.0833	2.7490		
CV	27.07%				

4. Conclusions

Degermed and whole maize flours were packed in three packaging materials (LDPE, HDPE and ALF) and stored for seventy days. The various biochemical qualities viz. moisture content, protein, fat, FFA, total acid and ash and textural properties of the flour dough were determined at storage interval of ten days. The minimum changes in biochemical qualities were found in aluminium-laminated foil during storage of both the flours (whole maize and degermed maize flours). It was also found that degermed maize flour can be safely consumed up to 60 days. The textural properties of the dough increased with increasing storage period. Rehydration time of 10 to 20 minute gave the best dough for cutting and puncture properties that are more suitable for making chapatti and storage period of 40 days was observed as the best.

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