J Food Sci Technol (November 2014) 51(11):3154–3162
DOI 10.1007/s13197-012-0788-7

ORIGINAL ARTICLE

Storage influence on the functional, sensory and keeping quality of quality protein maize flour

D. Shobha · H. V. Dileep kumar · T. A. Sreeramasetty · Puttaramanaik · K. T. Pandurange Gowda · G. B. Shivakumar

Revised: 27 June 2012 / Accepted: 22 July 2012 / Published online: 28 August 2012

Abstract Apart from nutritional values functional and sensory properties affect the behavior of food system and its acceptability for consumption during storage. Hence keeping quality of maize flour (HQPM-7) with and without lime treatment(control) was studied in terms of functional (bulk density, pH, swelling capacity, water and oil absorption capacity, least gelation concentration, peroxide value), sensory (appearance, color, taste, texture, mouth feel and overall acceptability) and rolling parameters (water absorption by flour, rolling quality, diameter after baking) for a period of 6 months under room temperature (25±5 °C) in two types of packages viz, LDPE cover (P) and plastic box (B). Physical parameters such as length, breadth and thickness (11.26–10.52 mm, 9.67–9.14 mm, & 4.72–3.95 mm) were reduced in lime treated grains compared to control. Significant increase ($p \leq 0.05$) in ash content of lime treated flour (1.67±0.01 g) was observed compared to control (1.5± 0.02 g). Calcium content of lime treated maize flour increased significantly ($p \leq 0.05$) from 48 to 136 mg. There is a significant reduction in functional properties of flour after 3 and 2 months irrespective in polyethylene cover and plastic box. The properties like rolling quality, diameter after baking and water uptake by the flour were reduced significantly ($p \leq 0.05$) after 4 months of storage in treated and after 1 month in control samples. Sensory scores of roti (dry pan cake) decreased significantly after 3 months of storage with an overall acceptability score of 4.0 and 3.4. In control samples mean taste (3.6), mouth feel (3.8) as well as OAA scores (3.8) decreased after second month. Hence lime treated maize flour with added nutritional benefits is suitable for making rotis of good palatability and can be stored in LDPE covers up to 3 months.

Keywords Quality Protein Maize · Rolling quality · Water uptake · Functional qualities · Shelf life · Peroxide value

D. Shobha (✉) · H. V. D. kumar · T. A. Sreeramasetty · Puttaramanaik · K. T. P. Gowda · G. B. Shivakumar
Department of Food Science and Nutrition,
University of Agricultural Sciences,
ZARS, VC Farm,
Mandya 571 405 Karnataka, India
e-mail: shobhafsn@gmail.com

Maize (*Zea mays L.*) is the third important food crop after rice and wheat, and is a good source of carbohydrates, proteins, fats and some of the important vitamins and minerals. It contributes to various end uses such as poultry feed (51 %), human food (23 %), animal feed (12 %), starch (12 %) and 1 % each for brewery and seed (Parihar et al. 2011). Since it is cheaper than wheat and rice, has great utility as food throughout the world. Several million people especially in the developing countries derive their calorie requirements from maize. In spite of its rich nutritional value, has not been considered as complete food due to lack of two essential amino acids viz, lysine and tryptophan. However, this problem has been overcome by the development of quality protein maize (QPM), which has twice the quantity of essential amino acids (Jat et al. 2009). Whole maize products are used to a very small extent in India only to substitute for wheat in products for people allergic to wheat gluten. The way in which maize is processed and consumed varies greatly from country to country. Many people in India are not aware of method of processing like lime cooking of maize grains and its advantages like weakening of kernel cell walls to facilitate pericarp removal, degradation or solubilization of the endosperm periphery (Gomez et al. 1989). Other important effects of nixtamalization include increased bioavailability of niacin, improved protein quality, increased calcium content and reduction of afflatoxin (Bressani et al. 1990). The major byproducts of dry millings of maize includes flour, meal and grits which can be used in various culinary preparations like upama, idli, dosa, roti (unleavened flat bread), porridge as well as sweet and savoury dishes either alone or with other cereal and pulse combinations. Quality protein maize has got better potential for roti making owing to its high protein digestibility (78.5 %) compared to sorghum (70 %) (Kulamarva et al. 2009). Keeping quality of flour for long term use is utmost important to prevent hazards like mould, bacteria, oxidative rancidity, and changes in functional as well as sensory properties during storage.

Functional property (functionality) is defined as any property of a food or food ingredients, besides its nutritional value that affects its utilization (Pour-ELA 1981). These functional properties viz., pH, bulk density (BD), water absorption capacity (WAC), oil absorption capacity (OAC), swelling capacity (SWC), and least gelation concentration (LGC) are the intrinsic physicochemical characteristics which may affect the behavior of food systems during storage. Adequate knowledge of these physicochemical properties indicates the usefulness and acceptability for consumption.

The role of packaging is also equally important to keep intact the functional and sensory properties, so also it is a means of providing the correct environmental conditions for food or any other product in order to protect the product against microbiological, chemical or physical deterioration (Komolafe 2005). Since maize is rich in carbohydrates (68–75 %) and fat (3.0–4.5 %) the attack of Red Flour Beetle (*Tribolium castaneum*) is common in grain as well as in flour unless it is properly processed and packed in airtight containers which render it to be unsuitable for consumption. Hence the present investigation was carried out to know the best packaging material which retains functional and sensory and rolling properties of QPM flour to extend its shelf life.

Materials and methods

Grains of Quality Protein Maize hybrid (HQPM-7) were procured from AICRP (Maize), Uchani, Karnal (Haryana) were divided into two sets by subjecting one set of grains to lime treatment, and the other as control (without lime treatment). Lime treatment involves the addition of one part of whole maize to two parts of approximately one per cent lime (calcium hydroxide) solution (w/v 1:2) and the mixture was heated to 80ºc for 30 min and allowed to stand overnight. The following day cooking liquor was decanted and maize was washed 3–4 times to remove the excess lime and any impurities in the grain (Palacios-Fonseca et al. 2009). Physical parameters such as length, breadth, and thickness of (average of ten) grains were measured using "Digimatic caliper". Thousand grains were manually counted and weight was recorded in grams. Bulk density by Okaka and Potter (1977), and volume by water displacement method, while colour by visual observation. Lime treated as well as control grains were dried until the moisture percentage reaches to 10–11 % and dry milled in a laboratory mill. Immediately after milling nutritional composition was analyzed for moisture, protein, fat, ash, minerals and crude fiber according to standard procedures of AOAC (2000). Carbohydrate content was calculated by differential method, while magnesium and potassium were estimated by Versanate titration and Ranganna (1986) respectively.

For storage studies lime treated and control grains were ground three or four times consecutively to obtain the flour of 250 μm (60BS mesh) using domestic flour mill (Rajalakshmi Flour Mill). The whole fresh flour was divided into two parts; one part was stored in polyethylene bags (LDPE 200 gauge thickness) and another in plastic bottles (Pearl Pet Jars) since these are the common storage containers used for storing of flour. Fresh as well as stored samples (0–6 month) were drawn and analyzed for functional, sensory and rolling parameters. Bulk density was calculated as mass of the flour per unit volume (g/ml) as described by Okaka and Potter (1977). The water absorption and oil absorption capacity (WAC and OAC) were determined by the method of Beuchat (1977).

The method of Fleming et al. (1974) was used for swelling capacity. The least gelation concentration (LGC) of the flour was determined using the modified method of Coffman and Gracia (1977). For pH analysis, Samuel et al. (2004) method was followed with the aid of μ pH system 361 (systonics) at temperature of 27 °C. Peroxide value (PV) was estimated according to AACC (1990).

To know the acceptability of flour in terms of sensory parameters, rotis (unleavened dry pan cake) were prepared from fresh as well as stored flour (0–6 months) according to Murthy and Subramanian (1982) with slight modifications, where in approximately 30 g of flour was added with warm water (incremental addition) and allowed for gelatinization on a low flame for 60 s and kneaded into smooth dough. Water required to make the dough was recorded as ml/30 g of flour. Rolling quality i.e. diameter of the roti that is expanded with an equal amount of flour and diameter after baking were recorded using Scale in centimeters (cm). The rotis were subjected to sensory evaluation by a panel of 15 semi-trained judges on a 5 point hedonic scale (Ranganna 1986), and the data obtained from each treatment was subjected to analysis as described by Steel et al. (1997).

Results and discussion

Physical parameters such as length, breadth and thickness (11.26–10.52 mm, 9.67–9.14 mm, and 4.72–3.95 mm) were reduced in lime treated grains compared to control (Table 1). The colour of the untreated grains was lustrous orange

Table 1 Physical Properties of Maize grains before and after the lime treatment

Characteristics	Untreated grains (Control)	Lime treated grains
Length (mm)	11.269	10.527
Breadth (mm)	9.670	9.140
Thickness (mm)	4.725	3.952
Thousand grain weight (g)	307	277
Thousand grain volume (ml)	380	340
Bulk density (g/ml)	0.80	0.81
Colour	Lustrous orange yellow	Non lustrous orange yellow

Length, Breadth and Thickness values were average of ten grains

yellow, while the treated was non lustrous orange yellow. This even holds good for flour colour. The dull colour of the alkali treated flour is due to the fact that the process of cooking resulted in gelatinization of the maize starch, allowing the cooked grains to imbibe lime solution, there by changing the colour of the samples (Samuel et al. 2004).

The perusal of Table 2 indicates that there was no significant difference in moisture content of the samples, but there was a significant increase in ash content of lime treated flour (1.67±0.01 g) compared to untreated flour (1.5±0.02 g). Similar kind of increase in ash content from 1.17 to 1.34 for traditional and commercial nixtamalized flour was reported by Palacios-Fonseca et al. 2009, and this may be caused by calcium retained and absorbed in the kernel during lime cooking process. A decrease in fat content from 4.03±0.07 to 3.24±0.09 was noticed after the lime treatment. Steeping and nixtamalization process might have contributed to increase in dry matter lost of pericarp and germ tissues. Slight reduction in fibre content was observed after lime cooking (2.41±0.015 to 2.0±0.07 g) which again due to the loss of pericarp that occur during lime treatment (Gutierrez et al. 2007; Serna-saldivar et al. 1988).

A slight increase of protein content from 10.64 to 10.69 g was noticed in lime treated grains, this was well supported by Samuel et al 2004 study, where in protein content increased slightly from 8.14 in raw maize sample to 8.88 in the sample cooked for 30 min in lime solution. Work done by other researcher's showed comparable amounts of protein in alkaline-cooked corn products compared to original grain, which has been attributed to a concentration effect (Gomez et al. 1987; Serna-saldivar et al. 1988). There was a significant increase ($p \leq 0.05$) in calcium content of lime treated maize flour (136 mg) compared to control (48 mg). This may be due to the reduction of phytic acid in lime cooking (Bressani et al. 2004). Another researcher Palacios-Fonseca et al. 2009 also reported an increase in calcium content caused by the calcium retained and absorbed in the kernel during lime-cooking process, so also Sergio et al. (1991) reports increase of calcium from 11 to 163 mg/100 g after the lime treatment. There was a increase in iron content after lime cooking, on the other hand Bressani et al. 2004 observed no difference with respect to iron and zinc contents after nixtamalisation process. However other micro nutrients like phosphorus, potassium, and sulphur increased significantly ($p \leq 0.05$) after lime cooking.

The results presented in Table 2 showed that there was no change in bulk density of the treated flour up to 2 months in covers and 3 months in box stored samples. On the other hand it was stable up to 4 months in control samples. Our findings were in accordance with the findings of Adetuyi et

Table 2 Nutritional Composition of Quality Protein Maize grains before and after the Lime treatment

Nutritional composition (g/100 g)	Untreated (Control)	Lime treated
Moisture	10.21 ± 0.042^{a}	10.16 ± 0.006^{a}
Ash	1.50 ± 0.02^{a}	1.67 ± 0.01^{b}
Fat	4.03 ± 0.07^{a}	3.24 ± 0.09^{c}
Fibre	2.41 ± 0.015^{b}	2.0 ± 0.07^{c}
Crude protein	10.64 ± 0.06^{b}	10.69 ± 0.03^{b}
Carbohydrates	71.17 ± 0.97^{a}	73.31 ± 0.58^{d}
Calcium(mg)	48.0 ± 0.3^{c}	136.0 ± 0.6^{d}
Magnesium(mg)	132.8 ± 1.04^{c}	142.0 ± 0.35^{e}
Iron(mg)	2.12 ± 0.03^{b}	2.25 ± 0.03^{e}
Phosphorous(mg)	312.3 ± 2.52^{c}	345.0 ± 1.3^{e}
Potassium(mg)	218.0 ± 1.4^{a}	241.0 ± 2.5^{e}
Sulphur(mg)	117.6 ± 2.52^{d}	121.0 ± 1.47^{e}

Values are mean ± SD of three observations, $n=3$. Mean with different superscripts significantly ($P<0.05$)

al. (2009) who also reported reduction in the bulk density of germinated flour after a period of 12 weeks in two storage containers.

Water absorption capacity is an important functional characteristic in the development of ready to eat food from cereal grains, since high water absorption capacity may assure product cohesiveness. The lower water absorption capacity of treated samples (187.3 %) compared to control (200.3 %) indicates that at 1 % lime concentration, the starch hydroxyl sites in the maize might have been saturated resulting in the decreased water absorption as observed by Bryant and Hamaker (1997). Soaking in water was found to reduce the water absorption capacity of pigeonpea flours compared to raw flour (Okpala and Mamah 2001). WAC % decreased significantly from 187.3 to 160.3 in plastic bottles and 158.34 in polyethylene covers over a period of 6 months. Significant reduction in WAC was observed in both the samples after 4 months of storage period, irrespective of the packaging material (Tables 3 and 4). However our values are lower than the values reported by Adetuyi et al. (2009) for unmalted maize (220 %), and maize + soybean blend (280 %). On the other hand Sosulski et al. (1976) reported a range from 92 % for mungbean flour (*Vigna radiata*) to 270 % for the Great Northern bean (*Phaseolus vulgaris*), and water absorption capacity of 271.7±0.6 % was reported for maize flour by Fasasi et al. (2006). Hence, the water absorption capacity depends on protein content, nature and type of proteins, hydrophilic properties of proteins which in turn related to polar groups such as carbonyl, hydroxyl, amino, carboxyl and sulfhydryl groups, also varies with the number and type of polar groups (Kuntz 1971). Crude protein and crude fibre contributed to higher water absorption in maize flour, Paul and Ayernor (2002).

The oil absorption capacity is a critical assessment of flavor retention and increases the palatability of foods (Kinsella 1976). The initial OAC of the flour was 140 % and it increased significantly over a period of 6 months in both the packages (147.67 in B, 146.67 % in P; Table 3) even in control samples there was a significant increase in OAC in both the packages. However, the percent of increase was less in treated samples. Adetuyi et al. (2009) reported an OAC of 180 % for malted blend and 160 % for unmalted blend and it was increased significantly in the first 3 weeks of storage. Different researchers worked on oil absorption capacity of pulses showed a significant variation in OAC% (Beuchat 1977; Sosulski et al. 1976; Sosulski and Fleming 1977). However, in our study the OAC % increase was found to be non significant up to 3 months (142 %) in lime treated as well as control polyethylene covers. Oil absorption is mainly attributed to the physical entrapment of oil and is related to the number of non polar side chains of fats (Kinsella 1976; Lin et al. 1974). The lower oil absorption (WAC 187.3 % and OAC 140 %) of the flour compared to

Table 3 Effect of storage (25–30 °C) on functional properties of Quality Protein Maize flour (Treated)

Storage period, months	BD g/ml		WAC%		OAC%		SWC g/g		LGC%		pH		PV mEq/kg fat	
	B	P	B	P	B	P	B	P	B	P	B	P	B	P
0	0.61	0.61	187.3	187.34	140.0	140.0	2.92	2.92	6.0	6.0	6.13	6.13	0.60	0.60
1	0.61	0.61	184.0	188.0	142.0	141.0	2.75	2.82	6.0	6.0	6.08	6.05	0.68	0.65
2	0.60	0.61	181.0	186.0	143.0	141.0	2.72	2.82	6.0	6.0	6.02	6.05	0.76	0.74
3	0.60	0.60	174.6	181.0	145.0	142.0	2.51	2.61	8.0	6.0	6.02	5.95	0.81	0.80
4	0.59	0.60	171.0	176.67	144.34	143.0	2.12	2.34	8.0	8.0	5.85	5.98	0.85	0.86
5	0.58	0.60	162.0	160.0	142.0	142.0	1.90	2.10	8.0	8.0	5.62	5.80	0.96	0.93
6	0.58	0.60	160.3	158.34	147.67	146.67	1.92	2.11	8.0	8.0	5.68	5.80	1.12	0.97
	F-value	CD (0.05)	F-value	CD (0.05)	F-value	CD (0.05)	F-value	CD (0.05)	F-value	CD (0.05)	F-value	CD (0.05)	F-value	CD (0.05)
Packaging	709.22*	0.001 (0.0)	34.97*	0.843 (0.290)	16.37*	0.701 (0.239)	1609.8*	0.2 (0.001)	–	–	194.79*	0.11 (0.004)	93.26*	0.07 (0.002)
Months	302.73*	0.001 (0.0)	48.83*	1.578 (0.543)	34.25*	1.214 (0.141)	8333.3*	0.3 (0.001)	–	–	542.80*	0.18 (0.007)	125.6*	0.13 (0.004)
M×P	136.74*	0.142 (0.001)	11.30*	2.231 (0.768)	1.88 ^{NS}	NS (0.585)	763.15*	0.06 (0.002)	–	–	29.55*	0.028 (0.010)	41.84*	0.18 (0.006)

BD bulk density; *WAC* water absorption capacity; *OAC* oil absorption capacity; *SWC* swelling capacity; *LGC* least gelation concentration, *pH* hydrogen ion concentration; *PV* peroxide value, *0–6* months interval, *NS* non significant. * Significant at 5 %, values within the parenthesis indicate SEm ± values, n=3

Table 4 Effect of storage (25–30 °C) on functional properties of Quality Protein Maize flour (Control)

Storage period, months	BD g/ml		WAC%		OAC%		SWC g/g		LGC%		pH		PV mEq/kg fat	
	B	P	B	P	B	P	B	P	B	P	B	P	B	P
0	0.64	0.64	200.3	200.0	180.3	180.4	2.34	2.84	6.0	6.0	6.53	6.53	0.56	0.56
1	0.64	0.64	197.3	198.2	181.6	181.3	2.15	2.82	8.0	6.0	6.60	6.50	0.59	0.59
2	0.65	0.64	195.0	192.1	183.6	182.6	2.10	2.10	8.0	6.0	5.49	6.40	0.64	0.65
3	0.64	0.64	183.4	181.0	184.8	184.0	2.10	2.10	10.0	8.0	5.17	5.80	0.85	0.80
4	0.60	0.61	179.5	172.4	186.0	186.0	1.95	2.15	12.0	10.0	5.07	5.70	0.92	0.96
5	0.59	0.58	163.5	161.1	188.0	187.1	1.90	2.01	12.0	12.0	5.01	5.42	1.33	1.35
6	0.50	0.51	163.4	160.2	191.0	188.0	1.93	1.90	12.0	12.0	4.89	5.11	2.03	2.13
	F-value	CD (0.05)	F-value	CD (0.05)	F-value	CD (0.05)	F-value	CD (0.05)	F-value	CD (0.05)	F-value	CD (0.05)	F-value	CD (0.05)
Months	210.04*	0.151 (0.052)	691.14*	26.664 (10.053)	121.70*	9.72 (3.344)	1638.06*	0.62 (0.262)	–	–	1068.49*	0.4 (0.648)	5846.62*	0.449 (0.449)
Package	0.031^{NS}	0.001 (0.00)	29.44*	4.308 (1.482)	19.04*	1.72 (0.592)	1775.20*	0.355 (0.122)	–	–	7937.10*	0.717 (0.247)	80.76*	0.026 (0.076)
M * P	210.51*	0.074 (0.214)	700.26*	66.427 (22.851)	129.92*	14.20 (4.886)	2388.94*	1.301 (0.447)	–	–	1300.54*	2.901 (0.998)	5911.65*	0.709 (2.061)

BD bulk density; *WAC* water absorption capacity; *OAC* oil absorption capacity; *SWC* swelling capacity; *LGC* least gelation concentration, *pH* hydrogen ion concentration; *PV* peroxide value, *0–6* months interval, *NS* non significant, *: Significant at 5 %. Values within the parenthesis indicate SEm ± values, $n=3$

Table 5 Effect of storage on mean sensory qualities of maize roti (treated)

Characteristics	Storage (25–30 °C) period, months										F-value		SEm ±	CD (0.05)
	0		1		2		3		4		Between samples	Between months		
	P	B	P	B	P	B	P	B	P	B				
Appearance	4.6	4.6	4.3	4.0	4.1	3.8	4.0	3.5	3.9	3.5	2.13^NS	2.68^NS	0.24	0.60
Color	4.6	4.6	4.1	3.5	4.1	3.5	4.0	3.7	3.9	3.4	13.98**	7.81*	0.13	0.50
Texture	4.0	4.0	4.0	3.8	3.9	3.4	3.9	3.5	3.4	3.2	14.54**	20.14**	0.08	0.19
Taste	4.3	4.3	4.1	4.0	4.0	3.8	4.0	3.4	3.6	3.1	4.46^NS	9.68**	0.14	0.33
Mouth feel	4.2	4.2	4.2	3.8	4.1	3.8	4.0	3.6	3.8	3.0	18.10**	14.30**	0.12	0.29
OAA	4.5	4.5	4.3	4.0	4.2	4.0	4.0	3.4	3.8	3.2	12.83**	9.04**	0.15	0.36

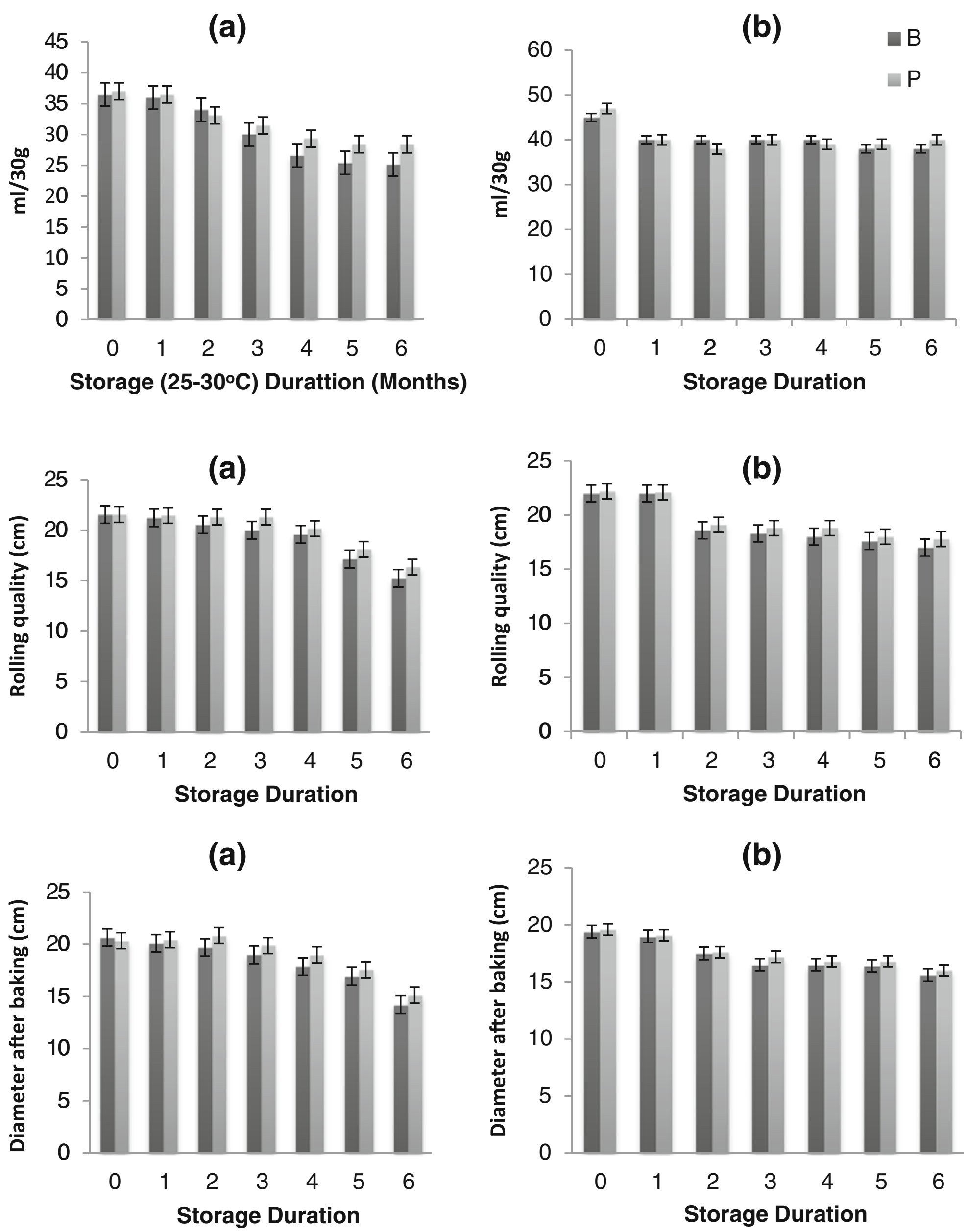

Fig. 1 Effect of storage on physical quality characteristics of maize flour (**a**) treated and (**b**) control maize flour. **B**: plastic box, **P**: LDPE covers. Values are mean ± SE, $n=3$

water absorption (Table 3) suggested that the major proteins in maize grain are predominantly hydrophilic in nature.

The swelling capacity of the flour is the volume of expansion of molecule in response to water uptake which it possessed until a colloidal suspension is achieved or until further expansion and uptake is prevented by intermolecular forces in swelled particle. There was no difference ($p\leq0.05$) in SWC% up to 2 and 4 months respectively in bottle and cover samples of treated flour (Table 3) where as in control sample irrespective of the packaging material swelling capacity reduced after 3 months (Table 4). Similar findings were reported by Leach et al. (1959). The decrease in SWC during storage in two types of containers (B and P) for 12 week storage period for malted maize and unmated maize + soybean blend was observed by Adetuyi et al. (2009).

Gelation may be defined as protein aggregation phenomenon in which polymer-polymer and polymer-solvent interactions, attractive and repulsive forces are so balanced that a tertiary network or matrix is formed and which is capable of immobilizing or trapping large amounts of water. Further gelation is affected by protein concentration, other protein components in a complex food system, non protein components, pH, reducing agents and heat treatment condition (Schmidt 1981). As depicted in Tables 3 and 4 LGC % increased as the storage period progressed in treated as well as control samples. There was a marginal difference in LGC values over the months in both the packages. The LGC of maize tilapia flour blend ranged from 4 % to 6 % as reported by Fasasi et al. (2006). Adetuyi et al. (2009) reported 8 % LGC for unmalted maize soybean blend and 4 % for malted flour, and which differed marginally over a period of 12 weeks. Obatolu and Cole (2000) also observed reduction in the LGC of cowpea and malted maize blend. These variations in LGC could be attributed to the relative ratios of different constituent proteins, carbohydrates and lipids in the flour sample. Sathe et al. (1982) reported that interactions between such components play a significant role in the functional properties.

Fresh lime treated flour had a pH of 6.13; similar pH value was reported by Samuel et al. (2004) for lime treated grains. There was no significant ($p\leq0.05$) difference in the pH value (6.02: B, 5.95: P) up to 3 months of storage (Table 3). As the storage period progressed, the pH value decreased in both the packages compared to fresh flour. On the other hand significant change was noticed in the pH of control samples from second month itself (Table 4). The pH value for unmalted maize was reduced after 12 weeks of storage period as reported by Adetuyi et al. (2009). This clearly indicates the turning of flour from neutral to slight acidic nature and this was well supported by sensory scores (Tables 4 and 5). This flour acidity increases owing to the accumulation of linoleic and linolenic acids which are slowly oxidized; hence solubility of the protein decreases (Kent 1978).

Peroxide values usually used as an indicator of deterioration of fats, as oxidation takes place. The double bond in the unsaturated fatty acids is broken down to produce secondary oxidation products which in turn causes rancidity (Ihekoronye and Ngoddy 1985). Peroxide values were stable up to 2 month (B) and 3 month (P) in treated samples. As the storage increased peroxide values increased in both the samples. This agreed with the observation of Gahalwat and Sehgal (1992) that the peroxide value and fat acidity of weaning food developed from locally available food stuffs increased with increase in storage period. On the other hand Kwaku et al. (2004) reported a PV of 1.64±0.38 for cowpea groundnut blend miso like product and the reason for increase in the peroxide value is that oxidation of fat increases the peroxide percentage in the product. Similar results were reported by Eagan et al. 1981, who investigated that the peroxide value of fresh oil and fats is usually below 10 meq/kg and for rancid oils and fats is above 20 meq/kg. Maize flour treated and control samples exhibited a

Table 6 Effect of storage on mean Sensory scores of roti (Control)

Characteristics	Storage (25–30 °C) period, months										F-value		SEm ±	CD (0.05)
	0		1		2		3		4		Between samples	Between months		
	P	B	P	B	P	B	P	B	P	B				
Appearance	4.5	4.5	4.5	4.2	4.4	4.0	4.2	3.6	4.1	3.2	20.54**	5.06*	0.15	0.36
Color	4.2	4.2	4.1	4.0	4.1	3.8	4.0	3.6	3.9	3.2	15.84**	6.07*	0.13	0.30
Texture	4.3	4.3	4.3	4.1	4.2	4.0	4.0	3.8	3.9	3.4	15.90**	11.25*	0.10	0.23
Taste	4.4	4.4	4.4	4.3	3.6	3.6	3.2	3.0	3.2	3.6	13.17**	8.59*	0.10	0.24
Mouth feel	4.5	4.5	4.4	4.2	3.8	3.8	3.6	3.2	3.4	3.2	17.19**	8.27*	0.11	0.27
OAA	4.2	4.2	4.1	4.0	3.8	3.8	3.6	3.2	3.6	3.0	13.51**	4.76*	0.13	0.31

P Polythene cover, *B* Plastic box, *0–4* Storage period (months), *OAA* overall acceptability. Score pattern: 1-Poor, 2-Fair, 3-Good, 4-Very good, 5-Excellent. *: Significance at 5 %, **: Significance at 1 %; Values are mean of three observations, $n=15$

peroxide values well within the BIS limits (<10 meq/kg of fat) in the present study.

Perusal of Fig. 1 indicates that the water uptake by 30 g of flour was 40 ml initially, which decreased as the months of storage increased in treated as well as control samples but the decrease was more in control samples after 1 month of storage in both the packages, while the treated samples were stable up to 3 months in cover and 2 months in box storage. Studies by Subramanian et al. 1983 showed that the water absorption of different sorghum cultivars was varied from 36 to 43 ml/50 g of flour, indicates that the maize flour has a higher water requirement compared to sorghum flour. There was no change in rolling quality and diameter after baking up to 3 months in treated covers, but the control samples showed decreasing trend from second month.

The mean sensory scores for lime treated (Table 5) samples revealed that the overall acceptability (OAA) scores were very good up to third month of storage (4.0) in covers while box retained up to 2 months. Texture and taste of the roti decreased significantly ($p \leq 0.05$) after fourth month of storage (3.4 (P) and 3.2 (B) for texture, 3.6 (P) and 3.1 (B), for taste). In control samples (Table 6) mean taste (3.6) and mouth feel (3.8) as well as OAA scores (3.8) decreased after second month of storage, which is due to the undesirable flavor and bitter after taste (mouth feel) observed in control samples of both the packages. While no such undesirable observation was made in treated samples that might be due to the lime water treatment to the grains. Hence the flour as well as rotis retained good aroma as well as taste (Table 5). This is in agreement with Bressani et al. (1990), where in the advantages of lime water treatment to maize includes increased digestibility, and palatability. Rotis rolling quality and diameter after baking decreased after 4 months indicating that the rotis could not be rolled into thin forms, might be due to the lower water uptake by the flour (Fig. 1) which in turn supported by Hart et al. (1970), who also have reported a lack of consistency and elasticity in sorghum dough at lower moister contents; while increasing the moisture content only lead to a batter like consistency. The dough broke apart easily and its properties did not improve upon kneading either. Hence sensory evaluation could not be done after 4 months of storage. This was supported by a significant decrease in pH values from neutral to slightly acidic (6.13 to 5.80 P), so also lipid hydrolysis indeed leads to free fatty acids formation, which imports a rancid off flavor to the product and they can also form complexes with amylase, thus decreasing water solubility (Mestres et al. (1997).

Conclusion

The present investigation revealed that the lime treated quality protein maize flour (QPM) having good palatability, aroma, increased amount of calcium, ash, magnesium, and iron contents can be stored in LDPE covers of 200 gauge thickness for a period of 3 months without affecting the functional (bulk density, pH, swelling capacity, water and oil absorption capacity, least gelation concentration, peroxide value) rolling parameters (water absorption by flour, rolling quality and diameter after baking) and sensory (appearance, color, taste, texture, mouth feel and overall acceptability) parameters. While the plastic boxes retained above parameters up to 2 months at ambient conditions. Hence lime treated maize flour with added nutritional benefits is suitable for roti making with good palatability can be stored in LDPE covers up to 3 months, to aid in long distance transportation and storage with a cautionary note of best before 3 months of packing.

Acknowledgements Authors are grateful to Project Director, Directorate of Maize Research, Pusa Campus, New Delhi for providing financial assistance and facilities to carry out the research work at AICRP (Maize) Centre, V.C. Farm, Mandya.

References

AACC (1990) Approved methods of analysis, 9th edn. American Association of Cereal Chemists. Inc, St. Paul

Adetuyi FO, Badejo OF, Ikujenlola AV, Omosuli SV (2009) Storage influence on the functional properties of malted and unmalted maize (*Zea mays* L ssp mays) and soybean (*Glycine max* L Merrill) flour blends. African J Food Sci 3(2):056–060

AOAC (2000) Official methods of analysis, 14th edn. Association of Official Analytical Chemists, Washington

Beuchat LR (1977) Functional and electrophorotic characteristics of succinylated peanut flour proteins. J Agric Food Chem 25:258–261

Bressani R, Benavides V, Acevedo E, Ortiz MA (1990) Changes in selected nutritient content and in protein quality of common and quality protein maize during tortilla preparation. Cereal Chem 67 (6):515–518

Bressani R, Turcios JC, Colmenares de Ruiz AS, de Palomo PP (2004) Effect of processing conditions on phytic acid, calcium, iron and zinc contents of lime cooked maize. J Agric Food Chem 52 (5):1157–1162

Bryant CM, Hamaker BR (1997) Effect of lime on gelatinization of corn flour and starch. Cereal Chem 74(2):171–175

Coffman CW, Garcia VV (1977) Functional properties and amino acid content of a protein isolate from mung bean flour. J Food technol 12:473–484

Eagan HRS, Kir, Sawyer R (1981) Pearson's Chemical Analysis of Foods. Chuch Hill Livingstone Pub. Edinburgh. London. Melbourne. New York

Fasasi OS, Ddeyemi IA, Fagbenro OA (2006) Functional and pasting characteristics of fermented maize and nile tilapia (oreochromis niloticus) flour diet. Pak J Nutr 6(4):304–309

Fleming SE, Sosulski FW, Filara, Humbert ES (1974) Viscosity and water absorption characteristic of slurries of sunflower and soy bean flours, concentrate and isolates. J Food Sci 39:188–190

Gahalwat P, Sehgal S (1992) Formulation and nutritional value of homemade weaning foods. Nutr Res 6:1171–1180

Gomez MH, Rooney LW, Waniska RD, Pffugfelder RL (1987) Dry corn masa flours for tortilla and snacks foods. Cereal Foods World 32(5):372–377

Gomez MH, Donough CM, Rooney LW, Waniska RD (1989) Changes in corn and sorghum during nixtamalization and tortilla baking. J Food Sci 54:330–336

Gutierrez E, Rojas-molina I, Pons-Hernandez JL, Guzman H, Augus-Angel B, Arenas J, Fernandez P, Palacios-Fonseca A, Herrena G, Rodriguez ME (2007) Study of Calcium ion diffusion in nixtamalized quality protein maize as a function of the cooking temperature. Cereal chem 84:186–194

Hart MR, Graham RP, Gee M, Morgan AI (1970) Bread from sorghum and Barley flours. J Food Sci 35(5):661–665

Ihekoronye AI, Ngoddy PO (1985) Integrated food science and Technology for the tropic. Macmilian publishers limited, London and Basinstoke, pp 253–257

Jat ML, Dass S, Yadav, Sekhar JC, Singh DK (2009) Quality Protein Maize for food and Nutritional security in India. Pusa, New Delhi

Kent NL (1978) Cereal technology with special reference to wheat (2nd 243 Edi). Macmillan Publishers limited, London and Banistoke, pp 253–257

Kinsella JE (1976) Functional properties of proteins in food. A survey. Crit Rev Food Sci Nutr 9:219–280

Komolafe EA (2005) Food packaging. A monograph. Publisher: Biotidara press and computers, Akure (Ondo State) Nigeria, p 81

Kulamarva GA, Venkatesh RS, Vijaya Raghavan GS (2009) Nutritional and rheological properties of Sorghum. Int J Food Properties 12:55–69

Kuntz ID (1971) Hydration of macromolecules, III. Hydration of polypeptides. J Am Chem SOC 93:514–516

Kwaku TD, Dennis V, Gbeddy (2004) Processing of a cowpea-groundnut blend into a miso-like product. J Food Sci Nutr 55:207–214

Leach HW, McCowen LD, Scoch TJ (1959) Structure of starch granule 1. Swelling and solubility patterns of various starches. Cereal Chem 36:534–544

Lin MJY, Humbert ES, Sosulki FW (1974) Certain functional properties of sunflower meal products. J Food Sci 39:368–370

Mestres C, Nago M, Akissoe N, Matencio F (1997) End use quality of some African corn kernels 2. Cooking behavior of whole dry-milled maize flours; incidence of storage. J Agric Food Chem 45:565–571

Murthy DS, Subramanian V (1982) Sorghum *roti*. I. Traditional methods of consumption and standard procedures for evaluation. Page 73 in: proc. Intl. Symp. Sorghum Grain Quality. October 28–31, 1981. (Sec 2). pp73. International Crop Research Institute for the Semi Arid Tropics, Hyderabad, India

Obatolu VA, Cole AH (2000) Functional property of complementary blends of soy bean and cow pea with malted or unmalted maize. Food Chem 70:147–153

Okaka JC, Potter NN (1977) Functional and Storage properties of cowpea–wheat flour blends in bread making. J Food Sci 42:828–833

Okpala LC, Mamah EN (2001) Functional properties of raw and processed pigeonpea (Cajanus cajan) flour. Int J Food Sci Nutr 52:343–346

Palacios-Fonseca AJ, Vazquez-Ramos C, Rodrguez-Gracia ME (2009) Physiochemical characterizing of industrial and traditional nixtamalized corn flours. J Food Eng 93:45–51

Parihar CM, Jat SL, Singh AK, Hooda KS, Chikkappa GK, Singh DK, Sai KR (2011) Maize Production Technologies in India. DMR Technical Bulletin 3. Directorate of Maize Research, Pusa campus, New Delhi 36

Paul H, Ayernor GS (2002) Appropriate processing and food functional properties of maize flour. African J Sci Technol 3:126–131

Pour-ELA (1981) Protein functionality: Classification, definition, and methodology. Page 1 in: Protein functionality in Foods. ASC Symp. Ser. 147. J.P. Cherry, ed. Am. Chem. Soc., Washington, DC

Ranganna S (1986) Hand book of analysis and quality control for fruit and vegetable products, 2nd edn. Tata McGrraw Hill Pub Co, New Delhi, pp 12–99

Samuel S-D, Beatrice C, Esther SD, Emmanuel A (2004) Effect of nixtamalisation on the chemical and functional properties of maize. Food Chem 86:317–324

Sathe SK, Desphande SS, Salunkhe DK (1982) Functional properties of winged bean proteins. J Food Sci 47:503–509

Schmidt RH (1981) Gelation and coagulation. Protein functionality in foods. ACS Symp Ser 147, J P Cherry ed Am Chem Soc, Washington, DC 131

Sergio O, Serna S, Lloyd W, Rooney LW, Greene (1991) Effect of lime treatment on the availability of Calcium in Diets of Tortillas and Rat growth and Balance studies. Cereal Chem 68(6):565–570

Serna-saldivar SO, Knabe DA, Rooney LW, Tanksley TD, Sproule AM (1988) Nutritional value of sorghum and maize tortillas. J cereal Sci 7:83–94

Sosulski FW, Fleming SE (1977) Chemical, functional, and nutritional properties of sunflower protein products. J Am Oil Chem 54 (2):100A–104A

Sosulski FW, Garratt MD, Slinkard AE (1976) Functional properties of ten legume flours. Can Inst Food Sci Technol J 9:66–74

Steel R, Torrie JH, Dickey D (1997) Principles and procedures of statistics. A biochemical approach, 3rd edn. McGraw Hill Book Co. Inc, New York

Subramanian V, Jambunathan R, Sambasiva RN (1983) Textural properties of sorghum dough. J Food Sci 48:1650–1673