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Development of maize-potato tortilla chips: A nutritious and low fat snack food

Sukhpreet Kaur and Poonam Aggarwal

Abstract
The present study was carried out to develop maize potato tortilla chips by substituting maize chips with fresh potato mash and dehydrated potato flour. Three potato cultivars *viz*. 'K.Chipsona-1', 'K. Chandramukhi (Processing cultivars) and 'K. Pukhraj' (table cultivar) were evaluated to find out their suitability for preparation of maize potato tortilla chips. The developed product was analyzed for physico chemical, bioactive and sensory properties. Moisture and ash content of the prepared product ranged 2.20 – 2.85% and 3.10 – 3.34%, respectively. Protein content was significantly ($p<0.05$) higher in control (without potato) chips compared to potato-supplemented chips. Oil uptake significantly decreased on supplementation with potato. A significant increase in the total phenolic content and total antioxidant activity of potato supplementated chips was found. Within the potato cultivars, tortilla chips prepared form 'K.Pukhraj' showed the highest total phenolic content and total antioxidant activity. Significant ($p<0.05$) difference in bioactive composition was observed in tortilla chips prepared from potato mash and potato flour. Also storage of maize potato tortilla chips for 3 months resulted in significant changes in total phenolic content and total antioxidant activity. Rancidity parameters in terms of free fatty acids and peroxide value showed slight but significant ($P<0.05$) increase with the progression of storage period. Results on the sensory quality evaluation revealed that tortilla chips prepared from all the three cultivars were highly acceptable for up to 3 months of storage. Also, no significant difference was observed in acceptability of the product prepared from fresh potato mash and potato flour, which indicates that these chips can be successfully prepared from both fresh as well as dehydrated potato.

Keywords: Potato, potato flour, tortilla chips, masa, nixtamilization, Phytochemicals, antioxidants

Introduction
Deep-fat fried products form the largest group of the marketed snack foods in India and are listed for their crunchy texture and fried aroma (Kulkarni *et al.*, 1994) [1]. The deep fried snacks, which evolved as snacks between meals in India, have been over a period of time, commercially exploited on a wide scale due to improved living standards, urbanization growth, preference of new generation for fast foods and rise in per capita income (Mehta *et al.*, 2011) [2]. In India, potato chips are the most common and popular snack food and presently constitute 85% of salty snack business worth Rs. 25 billion (Marwaha *et al.*, 2010, Pandey *et al.*, 2009) [3, 4]. Potato chips contain a significant amount of fat, reaching in many cases ~1/3 of the total product by weight (Mellema, 2003) [5]. This ensures a high level of satiety, but can also pose s risk. The consumer trend now a day is towards more healthy foods (Suna *et al.*, 2014) [6], creating the necessity of developing new products that offer variety, convenience, quality, cost-efficiency and are high on nutritive value.
Tortilla chips are Mexican corn snack products, which are produced by nixtamalization process, which involves alkaline cooking, steeping, washing and stone grinding of the kernals to produce masa. Corn masa is kneaded and moulded, then baked on a hot griddle and fried for tortilla chips (Moreira *et al.*, 1997, Kawas and Moreira, 2001) [7, 8]. These snacks provide instant energy, as they are rich storehouse of nutrients.
Tortilla chips are rich in B-vitamins and proteins. Calcium content of these products is also high because of alkali-treatment (nixtamalization). This process softens the pericarp, endosperm and gelatinizes the starch (Dasaur, 2001) [9]. The final oil and moisture content of tortilla chips are of almost 25% and 2%, respectively.
Potato is fourth most important food crop in the world. Potato is a wholesome food containing high levels of vitamins and important antioxidants, including phenolic acids, carotenoids and flavonoids (Gumul *et al.*, 2011) [10]. India is among the five major potato-producing countries in the world (Gahlawat and Sehgal, 1998) [11]. But inadequacies in its post-harvest handling, storage and transportation often pose a serious problem especially during the 'glut' season resulting in heavy post-harvest losses and wastage of this resourceful crop (Raj *et al.*, 2011) [12].

In order to overcome this problem, processing of potatoes is imperative.

Incorporation of dehydrated potato flour in *chapatti* (Singh *et al.,* 2005) [13], bakery products such as biscuits (Misra and Kulshrestha, 2003, Nazni *et al.,* 2009, Nazni and Pradeepa, 2010, Seevaratnam *et al.*, 2012) [14, 15, 16, 17], cookies (Chandrashekara and Shurpalekar 1984a, Singh *et al.,* 2003) [18, 19], bread (Chandrashekara and Shurpelekar, 1984b) [20] and extruded products (Bastos-Cardoso *et al.,* 2007, Aguilar-Palazuelos *et al.,* 2012, Nath *et al.,* 2012) [21, 22, 23] are reported in literature. However, no reports are available for incorporation of fresh potato in deep-fried snack products. So the study reported herein focused on supplementation of corn tortilla chips with potato.

Materials and methods

Raw material

Potatoes: Two potato cultivars having high dry matter content and known for better processing quality ('Kufri Chipsona-1', 'Kufri Chandramukhi') and one commonly cultivated variety ('Kufri Pukhraj') were evaluated for preparation of tortilla chips. Healthy, fully cured tubers of the above mentioned cultivars were obtained from the Vegetable Farms of Punjab Agricultural University (PAU), Ludhiana. Maize variety (PMH-1) was obtained from the Department of Plant Breeding and Genetics, PAU, Ludhiana. Common salt and refined soyabean oil was purchased locally.

Preparation of raw material

Fresh potato mash: Fresh potato tubers were washed, peeled and cut into thick slices (10 mm) using a rotary hand slicer. The slices were cooked in a pressure cooker for 15-20 minutes. The boiled potato slices were cooled and mashed.

Dehydrated potato flour: Potato flour was prepared by the method suggested by Kulkarni *et al.,* (1997) [24] with slight modifications (Fig. 1).

Raw potato tubers
↓
Peeling
↓
Slicing with rotary hand slicer (2-3 mm thick slices)
↓
Blanching to inhibit enzymatic browning (100^{o}C/6 minutes)
↓
Dipping of blanched potato slices in 0.25% potassium metabisulphite to inhibit non-enzymatic browning
↓
Loading in trays
↓
Drying in hot air cabinet drier (50^{o}C/5 hours)
↓
Coarse grinding
↓
Fine grinding in cyclotec mill (0.5 mm mesh size)
↓
Potato powder
↓
Packaging

Fig 1: Flow chart for the preparation of potato flour

Dehydrated masa flour: Nixtramalized soft dough called 'masa' is the raw material used to make tortilla chips. Nixtamilization or lime cooking, is the alkaline cooking of corn kernals in a calcium hydroxide solution. This process is responsible for important physicochemical, nutritional, and sensory characteristics of corn-based products including pericarp removal (Serna Saldivar *et al.,* 1992) [25], calcium incorporation into kernals (Serna Saldivar *et al.,* 1991) [26], improvement in niacin bioavailability (Pozo-Insfarn *et al.,* 2007) [27] and formation of flavor and color compounds that impart special organoleptic characteristics to these products (Serna Saldivar *et al.,* 1992) [25].

The procedure recommended by Dasaur, (2001) [9] was used for the preparation of dry masa flour with slight modifications. Corn kernals (100g) were cooked in water (300 ml), lime (1.5 g) for 1 ½ hour at a temperature of 90 ± 5^{o}C. The cooked corn kernals were then steeped for 15 hr at 30-40^{o}C. After steeping, washing was done to remove pericarp and excess lime. The nixtamal so obtained was coarsely ground in a mixture grinder to obtain nixtamalized corn dough called masa. The moisture consent of masa was 56.80 per cent. To obtain dry masa flour, the nixtamalized materials were dried in cabinet dryer at 35-40 ^{o}C for 12-14 hr. The dried material was then powdered in a cyclotec mill to fine powder. The moisture content of dry masa flour was 3.0 per cent.

Preparation of tortilla chips

Formulation

Maize-potato tortilla chips were prepared by the method of Quintero-Fuentes *et al.,* (1999) [28] with slight modification. Various proportions of potato (boiled and dehydrated) of each variety was tried to decide upon its level to be incorporated in dry masa flour. Tortilla chips were made with different potato concentrations (5%, 10%, 15%, 20% and 30%). Based on preliminary sensory trials, incorporation of 30 per cent fresh potato mash in the dry masa flour resulted in significant desirable changes in the sensory characteristics of the product. So this level was selected for the development of final product and to study the quality attributes of the prepared product.

Processing method

As per the standardized recipe, fresh potato mash (30 g) was blended thoroughly with dry masa flour (36 g), shortening (4 g) and salt (1g). The mix was hydrated with 34 ml of distilled water and kneaded uniformly to produce a soft dough (masa). Masa was allowed to rest in a plastic bag for 10 min. Pieces of fresh masa (20 g) were pressed and shaped into 1 mm thick flat disks using a manual tortilla press (Kalsi, India). The dough disks were baked in oven at a temperature of 240ºC for 2 minutes. The heat sets the structure, drives of most of the moisture, and changes the flavor slightly by creating small amounts of Millard (browning) reaction products (Stauffer, 1983) [29]. The moisture content of the chips after baking was approximately 27.5%. The baked chips were given a period of 10-15 minutes for conditioning so that all the moisture in it gets equilibrated. The sheeted masa disks were placed on plastic trays and cut manually with an equilateral triangle-shaped cookie cutter. Tortilla chips were then deep fat fried at 190ºC for 1 min in a laboratory scale deep fat fryer (Blaze Machinery, Mumbai, India). The fried chips were then cooled and packed. The control (without potato) tortilla samples were used for physico-chemical, phytochemical and sensorial comparisons. The method of preparation of tortilla chips is presented in Fig. 2.

Fresh potato mash/potato flour
↓
Mix with dry masa flour, salt and shortening
↓
Water → kneading
↓
Soft dough (masa)
↓
Divide masa into small dough balls (20 g)
↓
Shape into flat disks (1 mm thickness) by using tortilla press
↓
Bake at 240ºC for 2 min
↓
Cut into triangular shape
↓
Condition for 10-15 min at room temperature
↓
Fry in hot oil at 190ºC for 1 min
↓
Tortilla chips

Fig 2: Flow chart of preparation of maize-potato tortilla chips tortilla chips were also prepared by incorporating potato flour (instead of potato mash) into masa by using the same method as mentioned above.

Analysis

Physicochemical and phytochemical composition of raw ingredients and fresh tortilla chips

Tortilla chips were ground to a fine powder and analyzed for their physicochemical attributes. The moisture, ash, acid insoluble ash, acidity, protein contents, Free Fatty acids (FFA) and Peroxide value (PV) were determined by official methods (AOAC 2005) [30].

Total phenolic content was determined by Folin-Ciocalteu's colorimetric method (Singleton and Rossi 1965) [31]. Sample (5 g fresh tissue; 1 g dry ingredient) was refluxed with 80% aqueous methanol for 3 hours at 40ºC and residue was then further refluxed for 1 hour. After filtration of the extracts, the final volume was made to 100 ml with 80% aqueous methanol. For estimation of total phenol, 0.5 ml of this extract was mixed with 5 ml Folin-Ciocalteu reagent. The contents were mixed by manual shaking. After 3 minutes, 4 ml of saturated sodium carbonate solution was added. After standing for 30 min at room temperature, the absorbance was measured at 765 nm. The values were reported as mg of gallic acid equivalent (GAE) by reference to gallic acid standard curve and the results were expressed as milligrams of GAE per 100 gram.

Total antioxidant activity of the samples was estimated by DPPH (1, 1- diphenyl- 2-picrylhydrazyl) as described by Shimada *et al.*, (1992) [32] with some modifications. To 1 ml of methanolic extract of sample prepared as above, 1 ml Tris-HCl buffer (50mM, pH 7.4) was added. Then 2ml of 0.1 mM freshly prepared DPPH was added to the reaction mixture. The reaction mixture was shaken and incubated in the dark at room temperature for 30 min and the absorbance was read at 517 nm against blank (80% methanol and Tris buffer). The free radical scavenging activity was evaluated by comparing the absorbance with control solution to which distilled water was added instead of sample with 2ml of 0.1 mM DPPH and 1 ml 50 mM Tris-HCl buffer. BHT was taken as a standard at a fixed concentration of 5 mg/ml.

$$\text{Radical scavenging activity (\%)} = \frac{\text{Absorbance of control (0 minute)} - \text{Absorbance of sample (30 minute)}}{\text{Absorbance of control (0 minute)}} \times 100$$

Sensory quality analysis

For sensory evaluation, tortilla samples were evaluated by a panel of 10 judges using 9-point Hedonic scale for their sensory charcterstics like color, flavor, texture and overall acceptability. The scores were assigned from extremely liked (9) to disliked extremely (1).

Storage studies

Tortilla chips prepared from all the three cultivars were sealed in 200 gauge low density polyethylene (LDPE) bags and stored at room temperature (28-35ºC/RH 35-87%) for a period of 3 months. Storage stability of the product was assessed by determining changes in physiochemical and bioactive composition. Sensorial evaluation of the stored tortillas was done by a semi-trained panel of 10 judges using 9-point Hedonic scale.

Statistical analysis

All the analyses were carried out in triplicate and the mean and standard deviation were calculated using MS Excel software. Statistical analysis was performed by analysis of variance (ANOVA) to calculate critical difference of the data to statistically predict the significance. Significance was established at $p < 0.05$ levels

Results and Discussion

Proximate composition of raw ingredients

Comparison of physiochemical parameter (Table 1) indicated varietal difference in moisture contents among different potato cultivars. Fresh tubers of cultivar 'K. Pukhraj' had a higher percentage of moisture content which is indicative of its lower dry matter content compared to 'K.Chipsona-1' and 'K. Chandramukhi' which contained a lower percentage of moisture. Whereas almost equal moisture contents were observed in fresh potato flours prepared from all the three cultivars (Table 1). Protein, ash and fat contents of potato flours were similar to those noted in raw potatoes, indicating a non-significant ($p < 0.05$) effect of processing on the micronutrients of potatoes (Table 1). Data of protein, ash and fat content is in line with those reported by Gahlawat and Sehgal, (1998) [11], Sandhu and Parhawk, (2002) [33], Yadav *et* *al.,* (2006) [34].

Dry masa flour contained 3.0 per cent moisture, 9.12 per cent protein, 1.95 per cent ash and 2.24 per cent fat, respectively (Table 1). Gomez *et al.,* (1991) [35] reported 10.10 per cent moisture, 9.30 per cent protein, 1.50 per cent ash and 2.60 per cent fat in nixtamalized corn flour whereas Quintero-Fuentes *et al.,* (1999) [28] reported 15.0 per cent moisture and 8.75 per cent protein in dry masa flour. These differences might be related to the genetic variation and botanical origin among the maize varieties.

Fresh potato cultivars contained the highest level of total phenolics (40.20-64.30 mg GAE/100g). Processing of raw tubers in flour resulted in significant ($p < 0.05$) reduction in these phytochemicals. It has been reported that these bioactive compounds are relatively unstable to heat and get easily oxidized (Ahmed and Ali, 2003) [36]. So the present reduction in total phenolics might be related to water blanching operations. Similar losses during processing of raw tubers into flour were reported earlier by Roy Choudhuri *et al.,* (1993) [37] and Marwaha and Pandey, (2006) [38].

Potatoes are considered to have effective antioxidant properties. Antioxidant capacity as measured by DPPH radical scavenging method was maximum in raw cultivar 'K. Pukhraj' (63.50%), followed by 'K. Chandramukhi' (53.20%) and minimum in 'K.Chipsona-1' (38.10%) (Table 1). Processing of fresh tubers into potato flour led to significant ($p < 0.05$) reduction in their antioxidant activities. The antioxidant capacity declined by 45.14% ('K.Chipsona-1'), 51.40% ('K. Chandramukhi') and 67.08% ('K. Pukhraj').

This decrease in antioxidant capacity might be due to decrease in the levels of bioactive compounds such as phenolic compounds during leaching. Many research groups have documented a positive correlation between antioxidant capacity and phenolic content of potato and concluded that these compounds were mainly responsible for the antioxidant capacity (Kaur and Kapoor, 2002, Reyes *et al.,* 2005, Ah-Hen *et al.,* 2012) [39, 40, 41].

Table 1: Proximate composition of raw materials

Composition	'Kufri Chipsona-1'		'Kufri Chandramukhi'		'Kufri Pukhraj'		Dry masa flour	CD (p < 0.05)
	Raw tubers	Flour	Raw tubers	Flour	Raw tubers	Flour		
Moisture content (%)	75.69±0.90	6.02±0.20	75.70±0.80	6.05±0.25	84.69±0.50	6.15±0.19	3.00±0.10	0.86
Protein (%)	5.20±0.20	5.10±0.19	4.50±0.25	4.50±0.28	3.53±0.30	3.50±0.24	9.12±0.20	0.43
Ash (%)	0.98±0.29	0.94±0.20	2.18±0.15	2.11±0.21	1.73±0.09	1.76±0.05	1.95±0.10	0.24
Fat (%)	0.14±0.04	0.13±0.02	0.11±0.01	0.11±0.05	0.12±0.05	0.11±0.03	2.24±0.11	0.07
Total phenolic content (mg GAE/100g)	40.20±0.29	32.14±0.02	53.80±0.38	40.28±0.11	64.30±0.20	48.78±0.15	115.01±0.20	0.46
DPPH radical scavenging activity (%)	38.10±0.25	20.90±0.28	53.20±0.50	25.86±0.50	63.50±0.30	20.90±0.30	63.51±0.25	0.46

Value are mean ± SD, n = 3

NS – Non significant

Proximate composition of fresh tortilla chips

The proximate composition of fresh tortilla chips is presented in Table 2. Moisture and ash content of the prepared product ranged 2.20-2.85% and 3.10-3.34%, respectively. Significant ($p<0.05$) differences were found in the protein content of control and potato substituted chips. In control chips, the protein content was 9.00% that was found to be significantly ($p < 0.05$) higher than that of potato-incorporated chips, which had 7.50-7.87% protein (Table 2).

Addition of potato markedly affected the fat uptake by chips. Fat content of the control chips was the maximum (24.13%), which decreased to 21.14-23.15% with addition of potato (Table 2). This might be due to the hydrophilic character of potatoes. As explained by Bajaj and Singhal, (2007) [42], oil uptake during frying is a surface phenomenon. An increased hydrophobic character of the surface would result in increased oil uptake during frying. The ability of potatoes to reduce oil uptake in tortilla chips can be attributed to its hydrophilic character. Higher oil content is undesirable for health-conscious consumers as well as the industry because it increases product cost. The recommended fat content is 25.0% in tortilla chips (Gomez *et al.,* 1987) [43]. In comparison to this value, our products had lesser oil uptake which might be due to the variation in the raw material used.

The proximate composition of tortilla chips given by Almeida-Dominguez *et al.,* (1998) [44] was 9.70 per cent protein and 1.60 per cent ash. Whereas Dasaur, (2001) [9] observed 11.60 per cent protein, 0.27 per cent ash and 15.05 per cent fat in tortilla chips prepared from Indian maize. In comparison to these values, our product had different composition which might be due to the variations in the raw material used.

Results on the bioactive composition (Table 2) of tortilla chips revealed that control samples showed the least total phenolic content (100.01 mg GAE/100g) and total antioxidant activity (56.81%). There was a definite increase in the bioactive composition of the prepared product on inclusion of potato. This might be attributed to high total phenolic content and total antioxidant capacity of potato. Potato is considered an excellent source of a number of health-promoting phytonutrients such as phenolics and flavonoids, which are generally described as antioxidants (Hesam *et al.,* 2012) [45]. Within the potato cultivars, 'K.Pukhraj' tortilla chips had the highest total phenolic content and total antioxidant activity, followed by 'K.Chandramukhi' and least was observed in 'K.Chipsona-1' chips (Table 2). Higher concentration of phytochemicals in chips prepared from 'K.Pukhraj' might be attributed to their higher levels in the raw cultivar.

The values for total phenolic content of control tortilla chips was lower than those reported by Aguayo-Rozas *et al.,* (2012) [46] who documented 110.5 to 128.0 mg GAE/100g total phenolics in tortillas prepared from extruded pigmented Mexican maize flours.

Storage studies

Bioactive composition

Total phenolic content

The mean content of total phenolics of the tortilla chips was established to be 135.80 mg GAE/100g initially and this was found to decrease significantly ($p < 0.05$) to 115.10 mg GAE/100g, after 3 months of storage at room temperature (Fig. 3). This decrease in total phenolics might be due to degradation from the effect of heat, which increases with increase in storage temperature (Ezekiel *et al.*, 2013) [47]. According to Lemos and Sivaramareddy, (2013) [48], the stability of phenolics can be affected by several factors such as species geographic origin, harvest location, postharvest storage and processing. The loss in total phenolics accounted for 15.24% under room temperature.

Table 2: Proximate composition of fresh maize-potato tortilla chips

Composition	Control	Chips prepared from fresh potato mash			Chips prepared from potato flour			CD ($p < 0.05$)
		'Kufri Chipsona-1'	'Kufri Chandramukhi'	'Kufri Pukhraj	'Kufri Chipsona-1'	'Kufri Chandramukhi'	'Kufri Pukhraj	
Moisture (%)	2.85±0.08	2.41±0.10	2.20±0.09	2.74±0.10	2.73±0.10	2.25±0.08	2.44±0.08	0.08
Ash (%)	3.00±0.11	3.30±0.10	3.32±0.12	3.10±0.10	3.11±0.11	3.34±0.11	3.10±0.11	NS
Protein (%)	9.00±0.15	7.87±0.12	7.86±0.15	7.50±0.10	7.85±0.15	7.83±0.11	7.85±0.12	0.175
Fat uptake (%)	24.10±0.20	21.14±0.21	22.25±0.30	23.15±0.12	21.16±0.30	22.17±0.20	23.12±0.19	0.34
FFA (%)	0.21±0.01	0.20±0.02	0.22±0.01	0.20±0.02	0.21±0.01	0.20±0.01	0.21±0.02	NS
PV (meq O_2/kg fat)	0.51±0.01	0.50±0.03	0.52±0.02	0.51±0.02	0.51±0.01	0.50±0.01	0.50±0.2	NS
Total phenolic content (mg GAE/100g)	100.10±0.51	120.23±0.55	180.42±0.58	200.01±0.50	74.80±0.030	86.81±0.31	152.91±0.61	0.87
Antioxidant acidity (%)	56.81±0.25	67.42±0.35	70.12±0.50	75.08±0.20	60.48±0.35	63.83±0.20	70.48±0.38	0.44

Value are mean ± SD, n = 3
NS – Non significant

As far as the raw material is concerned, significant ($p < 0.05$) difference in total phenolics was observed in tortilla chips prepared from potato mash and potato flour (Fig. 3). The mean total phenolics in tortilla chips prepared from fresh potato mash and potato flour was 156.20 mg GAE/100g and 95.98 mg GAE/100g, respectively. The higher phenolics in potato mash tortilla chips might be due to presence of higher amount of phenolics in the raw potato tubers compared to potato flour (Table 1).

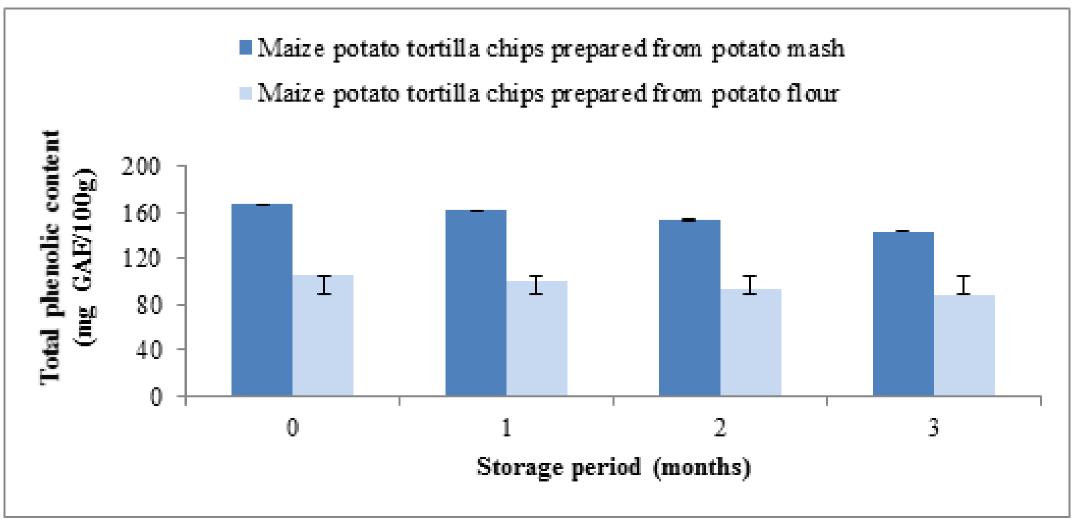

Fig 3: Effect of storage on total phenolic content of maize potato tortilla chips prepared from potato mash and potato flour. Values are mean ±SD, n = 3. Error bars represent SD of the means.

Total antioxidant activity

The free radical scavenging activities of aqueous methanolic extracts of tortilla chips supplemented with potato mash and potato flour are depicted in Fig. 4. There was a significant ($p < 0.05$) difference in total antioxidant activities of tortilla chips prepared from fresh potato mash and potato flour. Mean radical scavenging activities of methanolic extracts of potato mash and potato flour tortilla chips were in the range of 62.87% and 59.10%, respectively (Fig. 4). The lower antioxidant activity in potato flour chips might be due to lower antioxidant activity of potato flour compared to raw potato tubers (Table 1).

During storage period, mean antioxidant activity of tortilla chips decreased significantly ($p<0.05$) (Fig. 4). Mean radical scavenging activity in chips reduced from 67.91%, zero month storage to 52.73% after 6 months of storage. The decrease in the antioxidant activity might be related to decrease in the levels of phenolic compounds during storage (Klimczak *et al.*, 2007) [49]. Some researchers (Adom and Liu, 2002, De la Parra *et al.*, 2007, Lopez-Martinez *et al.*, 2011) [50, 51, 52] have reported that total polyphenolics are the most important contributors to the antioxidant capacity in maize. In the present study, the loss in total antioxidant activity accounted for 22.35% after 3 months of storage.

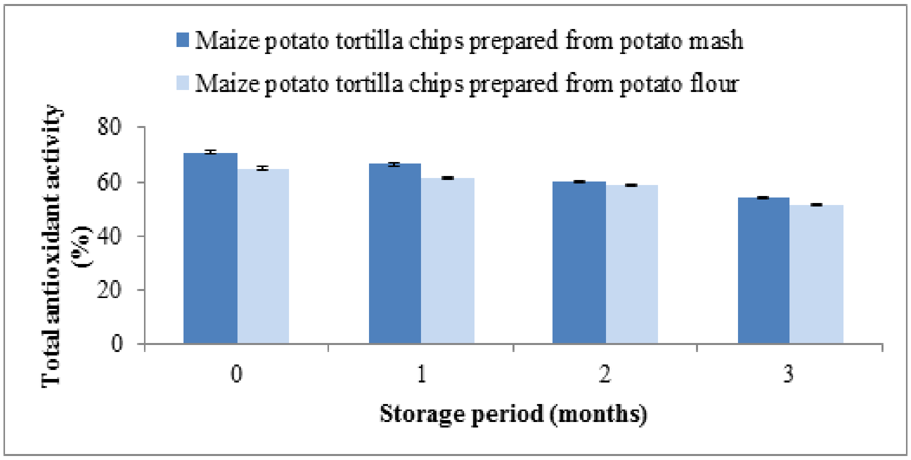

Fig 4: Effect of storage on total antioxidant activity of maize potato tortilla chips prepared from potato mash and potato flour. Values are mean ±SD, n = 3. Error bars represent SD of the means.

Rancidity parameters

Free fatty acids (FFA)

FFA are the products of enzymatic or microbial degradation of lipids. Determination of FFA gives information about stability of fat during storage. In the present study, the percentage FFA content of tortilla chips increased during storage and the increase was found to be statistically significant ($p < 0.05$) (Fig. 5). The initial mean FFA of chips was 0.21% which increased significantly to 0.39 per cent, after 3 months of storage. This might be due to the hydrolytic rancidity at elevated temperature (Khan *et al.*, 2011) [53]. Abong *et al.*, (2011) [54] reported significant increase in free fatty acids content in fried potato crisps during storage at room temperature (25-30ºC) for a total period of 24 weeks.

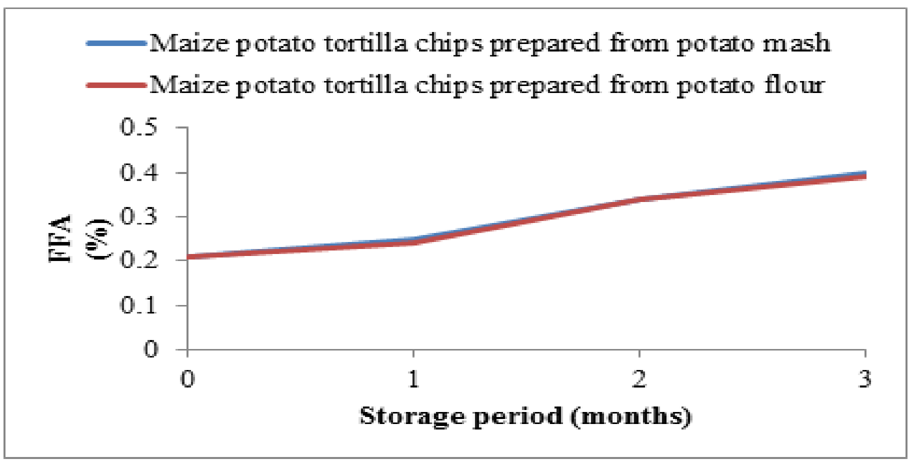

Fig 5: Effect of storage on FFA content of maize potato tortilla chips prepared from potato mash and potato flour. Values are mean ±SD, n = 3.

Raw material (i.e. potato mash and potato flour) used for preparation of tortilla chips had a non significant ($p < 0.05$) effect on the FFA content of prepared products. For tortilla chips, FFA content upto 0.55% is considered acceptable (Lusas and Rooney, 2001) [55]. In our study, the values for FFA content remained well within the acceptable limits during storage.

Peroxide value (PV)

The primary products of lipid oxidation are hydroperoxides (Kashyap *et al.*, 2012) [56]. Therefore, PV was used as an index to assess the level of lipid oxidation in tortilla chips during storage. There was a significant ($p < 0.05$) increase in the levels of peroxides in all the chips samples, irrespective of raw material (Fig. 6). PV increased from mean initial value of 0.50 to 2.18 meq O_2/kg fat, after 3 months of storage. This increase might be due to the auto-oxidation of the oil absorbed during deep-fat-frying (Kulkari *et al.*, 1994) [1]. In an earlier study, PV ranged from 0.12 to 7.4 meq O_2/kg fat during 60 days storage of fried potato crisps at room temperature (Abong *et al.*, 2011) [54]. In another study carried out on deep-fried potato snacks, PV ranged from 12.4 to 757 meq O_2/kg fat when stored for 180 days (Berry *et al.*, 1986) [57].

According to prescribed standards, PV value of fried tortilla chips must not exceed 10 meq O_2/kg fat (Lusas and Rooney, 2001) [55]. In our study, the values of PV were much below the critical level.

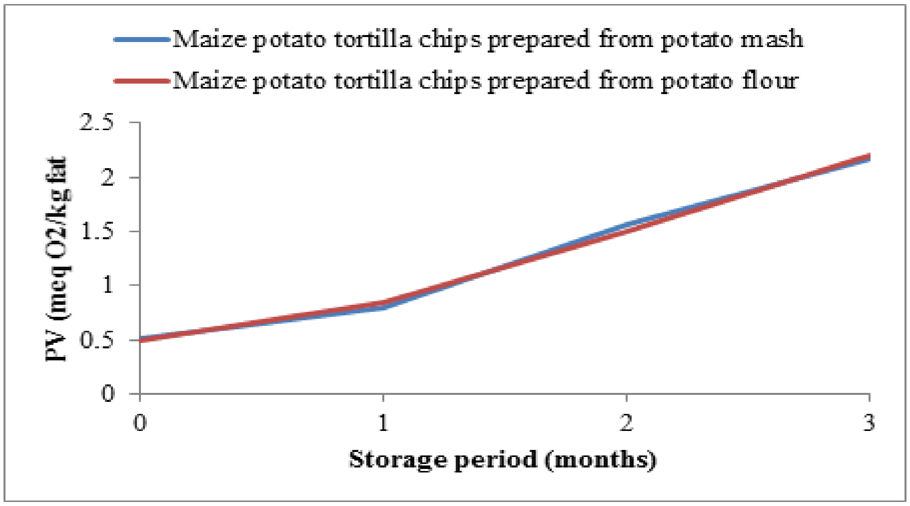

Fig 6: Effect of storage on peroxide value of maize potato tortilla chips prepared from potato mash and potato flour. Values are mean ±SD, n = 3.

Sensory quality evaluation of fresh tortilla chips

It is clear from Table 3 that there was no difference in sensory quality between tortilla chips prepared with either fresh potato mash or potato flour. These results indicate that maize-potato tortilla chips can be successfully prepared from fresh potato mash as well as dehydrated potato flour. Potato flour can be prepared when potatoes are cheap and used in off-season when potato prices are high. Within the cultivars studied highest preference was given to chips supplemented with ‘K.Pukhraj’, closely followed by ‘K.Chipsona-1’ and ‘K. Chandramukhi’ (Table 3).

Sensory quality evaluation of stored tortilla chips

Potato supplemented tortilla chips had better scores in terms of color, texture, flavor and overall acceptability as compared to control (without potato). Storage exerted a non-significant ($p < 0.05$) effect on the color of tortilla chips, regardless of cultivars and raw material but it significantly affected flavor, texture and overall acceptability of the stored products (Table 4).

The decrease in sensory scores during storage might be attributed to the physiochemical changes, which continue to occur at elevated temperatures. Feria-Morales and Pangborn, (1983) [58] evaluated sensory attributes of corn tortilla with substitutions of potato, rice and pinto beans. The authors concluded that substitution of corn with 24% potato resulted in improved texture, producing a softer and more flexible tortilla. Dasaur, (2001) [9] studied shelf life quality of tortilla and corn chips prepared from Indian maize varieties. Tortilla chips and corn chips remained acceptable upto 3 months of storage at room temperature (28-37^{o}C).

In the present study, potato incorporated tortilla chips of all the three cultivars were found to be highly desirable even after 3 months of storage.

Conclusion

A substantial amount of potato is spoiled and wasted due to inadequate cold storage facilities and insufficient post-harvest handling facilities. In addition, all the potato varieties are not suitable for processing and are considered as waste. These varieties can be utilized for the preparation of value added products. It can be concluded from the present study that maize potato tortilla chips were highly acceptable, more nutritious as compared to control ones and had good keeping quality. These products could be successfully prepared from table potato varieties, which are considered, unfit for processing and are wasted. The method of preparation is very simple, does not require any costly machinery and is specially suited to the cottage industry.

Table 3: Sensory evaluation of fresh maize-potato tortilla chips prepared from potato mash and flour

Sensory parameters	Chips prepared from fresh potato mash			Chips prepared from potato flour			CD ($p < 0.05$)		
	‘Kufri Chipsona-1’	‘Kufri Chandramukhi’	‘Kufri Pukhraj	‘Kufri Chipsona-1’	‘Kufri Chandramukhi’	‘Kufri Pukhraj	Cultivar (C)	Raw material (R)	CxR
Appearance	8.53±0.01	8.50±0.03	8.58±0.04	8.52±0.02	8.51±0.03	8.57±0.03	0.02	NS	0.03
Flavor	8.64±0.03	8.41±0.01	8.64±0.03	8.64±0.01	8.40±0.05	8.63±0.02	0.02	NS	0.03
Texture	8.43±0.01	8.32±0.03	8.68±0.2	8.42±0.01	8.32±0.01	8.69±0.01	0.02	NS	0.04
Overall acceptability	8.52±0.03	8.34±0.02	8.75±0.05	8.51±0.01	8.32±0.01	8.74±0.01	0.02	NS	0.03

Values are mean ± SD, n = 3

NS – Non significant

Table 4: Effect of storage on sensory quality of tortilla chips

Cultivar	Storage (months)	Appearance (color)	Flavor	Texture	Overall acceptability
Control	0	7.53±0.02	7.00±0.03	7.00±0.02	7.13±0.03
	1	7.52±0.01	7.03±0.01	6.90±0.04	7.14±0.01
	2	7.50±0.03	6.83±0.02	6.78±0.01	7.00±0.01
	3	7.50±0.02	6.70±0.01	6.80±0.02	7.00±0.02
'Kufri Chipsona-1'	0	8.53±0.01	8.64±0.03	8.43±0.01	8.52±0.03
	1	8.53±0.02	8.51±0.04	8.40±0.02	8.43±0.04
	2	8.52±0.02	8.40±0.04	8.31±0.06	8.32±0.03
	3	8.51±0.03	8.23±0.02	8.20±0.04	8.21±0.04
'Kufri Chandramukhi'	0	8.50±0.03	8.41±0.01	8.32±0.03	8.34±0.02
	1	8.50±0.01	8.35±0.02	8.28±0.02	8.27±0.04
	2	8.51±0.01	8.21±0.01	8.20±0.04	8.15±0.04
	3	8.49±0.01	8.11±0.03	8.10±0.03	8.00±0.05
'Kufri Pukhraj'	0	8.58±0.04	8.64±0.03	8.68±0.02	8.75±0.05
	1	8.58±0.01	8.58±0.04	8.60±0.02	8.50±0.04
	2	8.57±0.05	8.52±0.01	8.52±0.01	8.41±0.03
	3	8.57±0.02	8.48±0.02	8.40±0.01	8.34±0.02
CD (P < 0.05)					
Cultivar (C)		0.02	0.02	0.02	0.02
Storage (S)		NS	0.02	0.02	0.02
C x S		NS	0.03	0.03	0.03

Values are mean ± SD, n = 3
NS – Non significant

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