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Nisha Chhabra
Department of Food Science & Technology, Punjab Agricultural University Ludhiana, India

Amarjeet Kaur
Department of Food Science & Technology, Punjab Agricultural University Ludhiana, India

Sukhpreet Kaur
Department of Food Science & Technology, Punjab Agricultural University Ludhiana, India

Correspondence
S Nisha Chhabra
Department of Food Science & Technology, Punjab Agricultural University Ludhiana, India

Development of composite tortilla chips: An approach with improved quality

Nisha Chhabra, Amarjeet Kaur and Sukhpreet Kaur

Abstract
In the present investigation attempts have been made to develop composite tortilla chips with pearl millet, maize, soybean and whole pumpkin flour. Grain flours were obtained by milling in 'attachakki' while whole pumpkin flour was obtained by grinding and drying in oven. All flours were then analysed for physicochemical properties. All three grains were nixtamilized for the preparation of composite flour to be used for tortilla chip making. On the basis of sensory liking by the panellists the formulation of maize: pearlmillet: soybean, 60:30:10 was selected. This formulation was further substituted with whole pumpkin flour from 0-20%. Incorporation resulted in value addition and enhanced the quality of composite tortilla chips by decreasing its fat uptake and increasing the fracture force. Thus, the study was found to be successful at developing the gluten free tortilla chips having good nutritional profile, low oil uptake, good protein digestibility and better texture as corn tortilla chips. Composite tortilla chips would have vast scope in future market.

Keywords: Composite flour, composite tortilla chips, tortilla chips, whole pumpkin flour

1. Introduction
Prevalence of food allergy is increasing worldwide. It is estimated that risk is more in children (8%) than adults (5%) (Sicherer and Sampson, 2014) [30]. One of the major food allergen is wheat due to its gluten protein. The only treatment is gluten free diet, as there is no cure for this disease. Thus, gluten free food is the utmost requirement of such population. Pearl millet, maize and soybean are gluten free grains and have potential for utilization in gluten free products. Moreover, for diversification purpose, it is essential to increase the utilization of these crops.

Snack food is convenience food, which is generally eaten in-between the meals. Although snacks are eaten by every age group of people but these are mostly loved by children. Childhood is growing age that requires more energy and protein diet. Thus, snacks should be wholesome to fulfil their needs. Efforts are being done to develop healthy snacks for the market. Tortilla chips are a product of nixtamilized maize grains which give unique flavour, taste and odour to the product. Unfortunately, maize is not a balanced food because it lacks essential amino acid.

Many years ago, maize and pearl millet had maximum share in diet of human beings in most parts of India. However, modernization and busy lifestyle caused change in diet trends. These traditional grains also have good nutritional profile. Likewise, millets are superior to wheat and rice in terms of nutrition and provide vitamins, minerals and proteins (Rao, 1986) [25]. They also contain higher fibre and good source of micronutrients (Hadimani and Malleshi, 1993) [12]. Haddad *et al*. (2014) [11] have asserted that micronutrient deficiences and insufficiencies currently affect between 2 and 3 billion of the world's population resulting in a reduced potential to attain full physical and cognitive development. Thus, major consideration is being given to develop healthy ready to eat snacks. So, convenience foods are being made with traditional crops to fulfil the daily demands of nutrients. The unmet requirement is to improve the health status of people. In addition to this, blending of cereals with plant protein such as legumes can improve the nutritional profile of the product (Akpapunam and Darbe, 1994) [2]. Therefore, blend of maize, pearl millet and soybean has been made for the development of composite tortilla chips. Over the time, tortilla chips are becoming popular in all parts of world, despite their only traditional use in North and Central America. Studies for the development of tortilla chips using maize and decorticated sorghum as alone or blend with others have been documented. Initially, maize tortillas chips were prepared. Lately, sorghum tortilla chips and then decorticated sorghum tortilla chips have been prepared.

Sorghum tortillas have not met the people appeal due to off colour, social and physiological factors (Khan *et al*., 1980; Choto *et al*., 1985) [14, 5].

The technological challenge to develop the tortilla chips from composite flour and is expected to be overcome by addition of whole pumpkin flour. Though, whole pumpkin has rich source of nutrients such as vitamins, minerals, pectin and fibre. Pumpkin is seldom processed and used only for fortification. However, studies have suggested that addition of beta glucans could change the water absorption properties of flour and compete with starch for water, causing changes in gelatinization, thermal and rheological properties of masa (Cornejo-Villegas *et al*., 2010; Ramirez-Moreno *et al*., 2015) [6, 24].

Nixtamalization process causes the fibre losses from 70-90% in maize (Bressani *et al.*, 2001; Gutierrez *et al*., 2007; Fonseca *et al.,* 2009) [4, 10, 19]. Thus, addition of fibre rich ingredient could counteract the loss of the product. Moreover, rolling and breaking of tortillas could be minimized by addition of high fibre to the tortilla flours (Barros *et al*., 2010) [3]. According to Ishida and Steel (2014) [13], addition of dietary fibre can modify water absorption capacity, starch gelatinization which affects the quality changes of tortillas (Cornejo Villegas *et al*., 2010, Ramirez Moreno *et al*., 2015) [6, 24]. Addition of pumpkin flour would be a great option for fibre, improve nutritional profile and also enhanced physical and textural attributes of tortilla chips. Therefore, this snack would be healthy food for youth and children as well.

The purpose of research is to develop tortillas from composite flour (maize, pearl millet, and soybean) along with whole pumpkin flour to complete the nutritional profile and quality attributes of tortilla chips. The objectives of the present study were (i) assessment of physic-chemical properties of grains and whole pumpkin flour (ii) optimizing the level of grain flours for tortilla chips as per sensory liking (iii) effect of incorporation of whole pumpkin flour in composite flour on sensory and quality attributes of composite tortilla chips.

2. Materials and methods

2.1 Materials: Maize (PMH1), Soybean (SL958) and Pearl millet (PCB164) were procured from Director Seed, Punjab Agricultural University, Ludhiana. Pumpkin var. 'Punjab Samrat' was obtained from Department of Vegetable Science, PAU, Ludhiana. The physico-chemical properties of grains and whole pumpkin flour were accessed in milling lab (Department of Food Science and Technology, PAU, Ludhiana). The grains were stored in cold storage room at temperature 4±2 ˚C until analysis. For the chemical analysis, the grains were milled into whole flour using Burr mill (*attachakki*). Pumpkin was processed into whole pumpkin flour. Firstly, fully matured pumpkin fruit was washed in washer for 2-3 minutes. Rind and stalk was then discarded and whole fruit was diced into 4-5 pieces along with seed and peel. The shredded pieces were put on tray and let them dried at 60±2 ˚C for 72 hours followed by grinding into fine flour. The whole pumpkin flour was packed in polythene bags and kept in cold storage at 4±2 ˚C until analysis.

2.2 Composition characteristics: Moisture, protein, crude fat (AACC, 2000) [1], acidity, pH and ash of all flours were determined. Dietary fibre content of whole pumpkin flour in term of Neutral detergent fibre (NDF), acid detergent fibre (ADF), and hemicelluloses were also accessed according to Van Soest (1991) [34]. All parameters were evaluated on wet basis.

Table 1: Preparation of formulations using maize, pearl millet and soybean masa flour in different proportions

Formulation	Maize (%)	Pearl millet (%)	Soybean (%)
1	100	0	0
2	95	5	0
3	90	10	0
4	85	15	0
5	80	20	0
6	75	25	0
7	70	30	0
8	65	35	0
9	60	40	0
10	60	35	5
11	60	30	10
12	60	25	15
13	55	40	5
14	50	40	10
15	45	40	15

2.3 Preparation of tortilla chips: Composite tortilla chips were prepared with slight modifications by the method of Quintero-Fuentes *et al*. (1999) [23]. This process was consisted of two steps: masa flour preparation and tortilla chip making. 100 g grains of pearl millet and soybean were cooked with 300 ml of water and 0.5 g lime for 30 minutes while maize was cooked with 300 ml water and 1.5 g lime for 1.5 hour. Rest procedure for masa flour preparation was same for all the grains. Afterthat, cooked grains were steeped at 30-40 ˚C for 15 hours followed by washing and coarsely grinding. The grinded sample was oven dried at 40 ˚C overnight. At last, dried material was powdered in cyclotech mill and moisture content (approx. 4-5%) was checked. For tortilla chip making: masa flour (36 g), of each formulation (Table 1) was mixed with shortening (4 g) and salt (1 g). The mix was hydrated with optimum amount of distilled water and kneaded uniformly to produce soft dough (masa). Masa was allowed to rest in a plastic bag for 10 min. Dough balls of 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 240 ˚C for 2 minutes. 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 circular pizza cutter into both transverse direction. Tortilla chips were then deep-fat fried at 190 ˚C for 1 min in a laboratory scale deep fat fryer. The fried chips were then cooled and packed.

2.4 Sensory analysis: Sensory study was carried on tortilla chips developed from each formulation (Table 1). It was evaluated by panel of minimum ten semi trained judges on nine point hedonic scale for appearance, colour, aroma, texture and overall acceptability (Larmond, 1970) [15]. On basis of sensory study, most acceptable formulation was selected for further study.

2.5 Incorporation of whole pumpkin flour in composite flour: In the selected formulation, whole pumpkin flour was incorporated at level of 5, 10, 15, 20%. Tortilla prepared with the replacement of composite flour with whole pumpkin (5, 10, 15 and 20%). Then enriched composite tortilla chips were evaluated for sensory study, fat uptake ratio and texture attributes.

2.6 Texture: Stable Micro System Texture Analyser Model (TA-H di) was used to measure the peak force/fracturbility of tortilla chips. Tortillas were compressed with spherical ball probe 1/2inch at distance of 5mm and using speed of 2mm/sec. Five samples of tortilla chips were evaluated in triplicates and average value was taken.

2.7 Chemical and anti nutritional composition of composite tortilla chips enriched with whole pumpkin flour: Protein, moisture, ash (AACC, 2000) [1]; neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose (Van Soest, 1991) [34] were accessed as per the respective methods.

2.7.1 *In vitro* protein digestibility: The sample weight, containing 16 mg N was taken in triplicate and hydrolyzed with pepsin (1 mg of pepsin with 15 ml of 0.1 M HCL) at 37 °C for two hours. The reaction of pepsin was terminated by pouring 15 ml of 10% w/v tricholoroacetic acid. After that the mixture was filtered through whatman filter paper followed by evaluation for N fraction (Malwal, 1983).

$$\text{Protein digestibility (\%)} = \frac{\text{N in filtrate - N in pepsin}}{\text{N in sample}}$$

2.7.2 Tannins: Tannins were determined by the method documented by Saxena *et al.* (2013) [27]. The powdered material 2.5 g was weighed accurately. It was transferred to 100 ml volumetric flask followed by addition of 70 ml of distilled. Then, flask was heated for 30 minutes in boiling water bath. The volume was made to 100 ml with distilled water and allowed to cool. From the sample extract 0.5 and 1 ml of filtrate was taken followed by addition of 5 ml Folin-Denis reagent, 10ml saturated sodium carbonate and made up volume to 100 ml with distilled water. Absorbance was taken at 760 nm after 30 minutes. Standard curve was plotted as per Sastri (1962) [26] and Schanderl (1970) [28] methods.

2.7.3 Total phenols: Total phenols were determined according to method (Singleton *et al*., 1999) [31]. One g weight of sample in triplicate was taken and then refluxed with 50 ml of 80% methanol solution for two hours at 30 °C. The solution was filtered through whatman filter paper No. 1. The leftover sample was refluxed again with 50 ml of 80% methanol for 2 hours at 30 °C. The same step was repeated again for complete extraction. Both extracts were mixed and volume was made to 100 ml with distilled water. After that, 0.2 ml of extract, 0.8 ml of distilled water, 5 ml Folin-Ciocalteu reagent was mixed together and kept for 5 minutes. Then, 4 ml of saturated solution of sodium carbonate was poured into it. The colour was developed after fifteen minutes. Absorbance at 765 nm was taken. Other than the sample, 1 ml of distilled water was taken for the blank preparation. Rest the same steps were followed.

$$\text{Total phenol (mg /100 g)} = \frac{\text{Concentration of phenol from graph} \times \text{Final volume}}{\text{Weight of sample} \times \text{Aliquot taken}} \times 100$$

2.8 Microscopic studies: Morphological changes occur during the development of masa dough and tortilla chips of selected combination were compared. Both samples were mashed properly and oven dried at 40 °C overnight. Cooled and dried sample were then carefully mounted on double sided black carbon tape stuck to the stubs and then sputter coated with gold. Hitachi Scanning Electron Microscope (S-3400N) was used for taking images at different magnification levels.

2.9 Statistical analysis: The data was statistically accessed using CPCS version 1NCPCS1 [Om (0.1)]. One way analysis of variance (ANOVA) was used for finding significant difference (p<0.05) with Complete randomized design (Gomez and Gomez, 2010) [8].

3. Results and Discussion

3.1 Chemical Composition: The moisture content of grains namely maize, pearl millet, soybean and whole pumpkin flour was found to be 6.4%, 7.97%, 5.25%, 11.04% respectively. Among the flours studied, soybean had highest value of protein, fat, ash, NDF, ADF, pH and acidity. This was within the range as evaluated by Sharma *et al*. (2014) [29]. Thus, whole soybean flour supplementation in composite flour would be a major contributor in improving nutritional profile in terms of protein, fat, minerals, dietary fibre etc. It was revealed that whole pumpkin flour had highest value (1.32%), followed by soybean flour (0.94%), then pearl millet (0.42%) and lowest for maize (0.32%) respectively. The overall pH of all three cereals flour was found to be near the neutral pH. Soybean contained the highest ash content followed by pearl millet (1.75%) and then maize (0.95%). Whole pumpkin flour and whole soybean flour were found to be the richest source of dietary fibre. This fact is in agreement with the previous study (Peksa *et al.*, 2016) [21]. Maize composition is in good agreement with the previous study of Thakur *et al*. (2015) [33].

Table 2: Physico-chemical composition of grain and whole pumpkin flours (Average value ± SD)

Parameters	Flour			
	Maize	Pearl millet	Soybean	Whole pumpkin flour
Moisture (%)	6.4±0.05	7.97±0.31	5.25±0.12	11.04±1.02
Protein (%)	9.97±0.25	6.50±0.57	42.25±1.25	7.04±2.89
Fat (%)	4.57±0.18	5.55±0.02	20.40±1.21	18.12±1.21
Acidity (%)	0.32±0.04	0.42±0.03	0.94±0.09	1.32±0.04
pH	6.37±0.02	6.16±0.01	6.66±0.01	5.93±0.71
Ash (%)	0.95±0.01	1.70±0.06	5.55±0.04	7.58±1.21
NDF (%)	8.44±1.39	10.00±0.83	18.73±0.74	16.28±0.45
ADF(%)	3.42±0.23	4.92±0.51	17.84±2.13	13.42±0.42
Hemicelluloses (%)	4.54±0.49	5.41±0.25	0.165±0.09	2.97±0.21

3.2 Handling and sensory assessment of tortillas prepared from composite flours : Though, tortilla chips are formed of 100% nixtamilized maize flour but in this study these were prepared from different formulations that consist of maize, pearl millet and soybean. In this study, these were tried to be prepared from 100% maize masa and subsequently replaced with pearl millet masa from 0-40% followed by best combination with soy masa 0-15%. The masa of respective grains were prepared as illustrated earlier. The preparation technology revealed by replacing the maize masa with pearl millet masa, tortilla chips became less sheetable, showed dark color and were very fragile however, their taste was acceptable. Further, soybean was incorporated which gave fair texture and structure. However, the addition of soybean flour at level of 15% made the product bitter. Therefore, on basis of sensory acceptability, one best blend of tortilla chip (60:30:10; maize: pearlmillet: soybean) was selected.

Table 3: Handling and sensory scores of composite (maize: pearl millet: soybean) tortilla chips

Formulation	Sheeting	Cracks	Colour	Flavour	Taste	Crispiness	Overall acceptability
1	Fair	Few	8.33	8.67	8.33	6.33	7.96
2	Fair	Few	6.33	8.67	8.33	6.67	6.83
3	Fair	Few	4.67	8.00	8.33	6.67	6.83
4	Fair	Few	4.67	7.67	8.33	7.00	6.97
5	Seldom	Few	4.33	7.33	8.00	7.83	6.67
6	Seldom	Moderate	4.00	7.00	8.00	8.00	6.63
7	Seldom	Moderate	4.00	6.67	7.67	8.50	6.50
8	Seldom	Moderate	4.00	6.67	7.33	8.83	7.17
9	Seldom	Moderate	4.00	6.67	7.33	9.00	7.33
10	Seldom	Few	5.00	7.17	8.00	7.00	7.11
11	Seldom	Few	5.00	8.17	8.50	6.33	7.43
12	Fair	Moderate	5.00	6.17	6.83	6.00	6.00
13	Seldom	Few	5.00	7.28	7.17	8.77	6.33
14	Seldom	Few	5.00	8.17	6.83	8.33	5.83
15	Fair	Moderate	5.00	6.17	6.17	7.50	5.67
CD(p<0.05)			NS	0.59	0.55	0.50	0.53

3.3 Sensory assessment of tortilla chips developed by composite flour and whole pumpkin flour incorporated at different levels: Out of fifteen combinations of maize, soybean and pearl millet flour, one formulation was selected on basis of sensory and handling evaluation. The most acceptable formulation was used as reference or control. Sensory study was carried out with and without the addition of whole pumpkin flour at different levels (5, 10, 15 and 20%). The colour scores showed that there was no significant (p<0.05) difference among the different samples of tortilla chips. It might have been due to incapability of other flours to mask the dark color of pearl millet. Although the incorporation of whole pumpkin flour from 5-20% enhanced the flavour and taste whereas the dark colour of tortilla chips remained the same. In term of crispiness, tortilla chips were not distinguished by panellists. Therefore, crispiness was retained up to incorporation of 20% whole pumpkin flour.

Table 4: Effect of incorporation of whole pumpkin flour on quality attributes and sensory scores of composite tortilla chips

Level (%)	Attributes						
	Fat uptake	Fracture force	Colour	Flavour	Taste	Crispiness	Overall acceptability
Control	37.072	3.65	7.17	6.83	7.00	7.83	7.24
5.00	31.149	8.40	7.00	6.83	7.17	7.83	7.23
10.00	26.135	13.55	7.17	7.00	7.67	7.83	7.39
15.00	23.672	24.01	7.00	7.33	7.83	7.83	7.55
20.00	22.424	35.12	7.17	8.00	8.17	7.83	7.79
CD ($p \leq 0.05$)	0.926	2.17	NS	0.57	0.47	NS	0.10

NS Non significant

3.4 Quality attributes of tortilla chips: Fat uptake and texture are major substantial quality attributes of fried snacks. Potato chips have fat uptake up to 69% (Talburt, 1987) [32] while maize tortillas chips have fat uptake of 35% (Moreira *et al*., 1997) [18]. Fat uptake of tortilla chips is dependent on a number of factors. Due to low uptake, consumer demand for tortilla chips is growing day by day. The selected formulation without (referred as control) and with the whole pumpkin flour (0-20%) was evaluated for fat uptake content. The control value was within the range of oil uptake of already prepared tortilla chips at optimum baked and over baked conditions as quoted by Moreira *et al*. (1997) [18]. Table 4 shows that without and with addition of whole pumpkin flour at 5%, 10%, 15% and 20% level causes to decrease the fat uptake content 31.55%, 26.90%, 23.78%, 22.78% respectively. The moisture loss and oil uptake are interrelated and both are linear function of square root of time (Gamble *et al*., 1987; Pinthus *et al*., 1995; Moreira *et al*., 1997) [7, 22, 18]. With increase in moisture loss of high moisture food, more pores are developed which cause an increase in oil uptake ratio. Moreover, initial solid content and product density of food are inversely correlated with oil uptake content of finished product (Yamsaengsung and Moreira, 2002; Paul and Mittal, 1997) [35, 20] because both have relationship with moisture content. The data revealed that with incorporating of whole pumpkin flour in composite flour the fat uptake content

decreased. This means that incorporation of whole pumpkin flour at level 20% reduced fat uptake 3 fold which was good for health conscious people. This is probably because incorporation of whole pumpkin might have increased the product density and solid content which causes decrease in oil uptake.

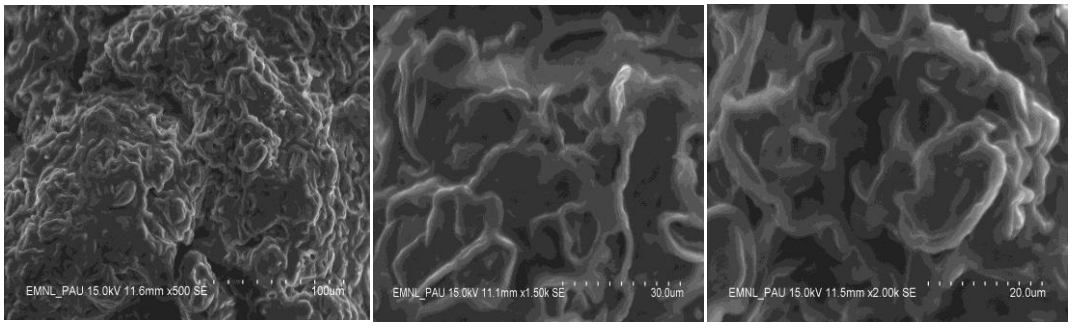
The graph signifies that the initial fracture of the sample was indicated by the first peak force from initial fracture and then follows a series of more minor fracture. Despite the lack of uniformity in fracture profile due to irregular shapes of samples there still appears to be repeatability in max force value. Greater value of fracture, harder is the sample. Quintero Fuentes *et al*. (1999) [23] reported that addition of sorghum flour (20%) in corn dry masa flour reduces the fracture force of tortilla chips from 6.19 N to 2.05 N. In this study, control composite tortilla chips had fracture force 3.65 N. On increasing the incorporation level of whole pumpkin flour from 0-20% in formulation caused increase in fracture force. These results could have been be due to addition of rich fibre source of whole pumpkin flour; likewise the previous study revealed that rolling and breaking of tortillas could be minimized by addition of high fibre to tortilla flours (Barros *et al*., 2010) [3]. Hence, this study has also supported that addition of fibre rich flour likely to improve the rolling and binding ability of tortilla chips. However, Ramírez-Moreno *et al*. (2015) did not report any change in the roll-ability of tortillas with and without fibre of dried cladodes.

3.5 Nutritional and anti-nutritional composition of composite tortilla chips: Addition of 20% whole pumpkin flour in formulation (maize: pearl millet:soybean-60:30:10) was found to be most acceptable formulation for tortilla chips. The final tortilla chips were evaluated for the nutritional and anti-nutritional attributes (Table 5). The data revealed that tortilla chips had 4.98% moisture, 14.2% protein, 5.7% ash, 45.4% NDF, 7.6% ADF and 8.2% cellulose etc. Moreover, these results are comparably higher than the previous studies which evaluated chemical composition of maize tortillas (Lecuona-Villanveva, 2012) [16].

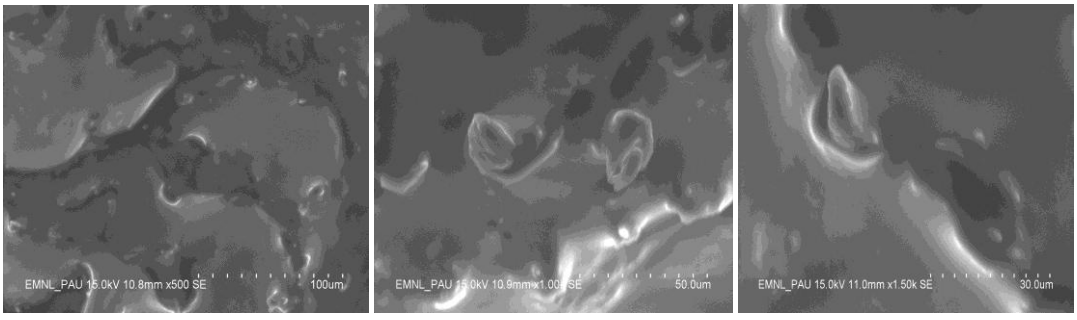
Table 5: Nutritional and anti-nutritional composition of final composite tortilla chips enriched with whole pumpkin flour (20% w/w)

Protein (%)	Moisture (%)	Ash (%)	NDF (%)	ADF (%)	Cellulose (%)	*In vitro* protein digestibility (%)	Tannins (µg/100 ml)	Total Phenols (mg/100 g)
14.2	4.98	5.7	45.4	7.6	8.2	78.8	2072	689.5

3.6 Microscopic studies: Microscopic structure seems to show that nixtamilized masa dough has partial loss of birefringence and dense networks are closely tangled with each other (Figure 1a, 1b). The structure is probably due to varied composition and different behaviour of protein in mixture of flours than maize alone. Microscopic study has not been presented on unbaked masa dough. However, previous studies on corn masa revealed that it has cohesive glue like structure which appear to hold masa piece together. This glue is probably composed of gelatinized and dispersed starch, hydrated and dehydrated protein matrix or free and emulsified lipids (Gomez *et al*., 1992) [9]. Starch granules are most disrupted, gelatinized particles and coalesce together and the extent of this change is dependent on the processing conditions and nature of the sample; likewise reported by Gomez *et al*. (1992) [9]. Tortilla chips with 20% incorporation of whole pumpkin flour seemed to have complete randomized continuous phase with few pores. According to Gomez *et al*. (1992) [9], on frying, tortilla chips lose their birefringence up to 95%. The internal core contains gel pieces which are completely gelatinized. The rest display strong birefringence because they are mainly present outside the surface and dehydrate first. Thus insufficient water is available for gelatinization. This study is in agreement with the study of Lujan-Acosta and Moreira (1997) [17].



(a)



(b)

Fig 1: Scanning electron micrographs of final (a) masa dough; (b) fried composite tortilla chips enriched with whole pumpkin flour (20%)

4. Conclusions

This study is found to be successful in development of composite tortilla chips enriched with whole pumpkin flour. Incorporation of whole pumpkin flour does not only enhance the nutritional profile of the product. It also improves the quality in term binding, roll ability, flavour and texture. Despite these outlined attributes addition of whole pumpkin flour could not mask the dark colour of finished product. During nixtamilization, fibre loss is major concern. This has also been overcome by incorporation of fibre rich source such as whole pumpkin flour. Besides having good acceptability, the composite tortilla chips also have improved nutritional profile, comparable texture, better quality then maize tortilla chips.

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