Effect of processing conditions on the quality characteristics of barley chips

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Abstract The aim of the present study was to study the effect of lime concentration, frying temperature and frying time on quality characteristics of barley chips. Effect of salt concentration and packaging material on the quality and stability of the product was also studied during 180 days of storage under ambient conditions. An increase in fat content of chips was observed with the increase in lime concentration, frying temperature and time, whereas a decreasing trend was observed in moisture content of chips. An increase in amylose content of chips was observed during frying. However, it was found that the amylopectin in chips decreased during frying as frying temperature and time was increased. An increase in colour difference (ΔE) and crispness was noted in chips during frying as frying temperature and time increased. With the increase in lime concentration (0.5 and 1.0 %) both ΔE and break force of chips was found decreased. The results further revealed that there was gradual decrease in fat (%) and amylopectin (%) during storage, whereas moisture (%) and amylose (%) increased during storage period. Organoleptic evaluation of the product revealed that scores of colour, texture, flavour and over all acceptability decrease during storage. However the treatment (salt 2 % and aluminium based laminate) recorded better score with respect to colour, flavour, texture and overall acceptability.

Keywords Barley chips · Frying temperature · Lime concentration · Amylose · Starch · Overall acceptability · Texture

Abbreviations

AAAC American Association of cereal chemists
AOAC Association of Official Analytical Chemists

Introduction

Barley (*Hordeum vulgare*) a member of family gramineae is the world's fourth most important cereal crop, after wheat, maize and rice. It grows best under cool dry conditions and matures more quickly than other cereals, thus it can be grown at broader latitudes and higher altitudes. (Hough 1975). It is the most drought tolerant cereal (Poehlman 1985). Russia ranks first in terms of production (17.9 million metric tonnes) followed by France (12.9 million metric tonnes), Germany (12.3 million metric tonnes), Ukraine (11.8 million tonnes), Canada (9.5 million metric tonnes). Barley production has been relatively stagnant to around 1.5 million tonnes over the past many years (Santosh 2012). Barley grain contains about 12.5 % moisture, 11.5 % protein, 69.9 % carbohydrate, 1.3 % fat, 3.9 % crude fibre, 1.2 % mineral matter, 0.025 % calcium and 0.215 % phosphorus (Anonymous 2006). It contains a sizeable amount of hydrocolloidal carbohydrates collectively referred to as β -glucans (mixed liner polymers of β -D glucopyranose), (Preece, and Mackenzie 1952; Fox 1982). Non starchy polysaccharides, β -glucans are a major component of the soluble dietary fiber implicated in hypocholesterolemia in chicks, humans and rats (Bhatty 1993).

Barley genotypes have been classified as hull less and hulled. Hull less cultivars have better nutritional value than hulled ones (Wang et al. 1997). The feed values of hulled

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barley is lower due to high content of fiber but hull less barley has a feed value equal to wheat and corn (Bhatty 1993). Hence for human consumption in India, mainly hull less barley is used after milling and dehusking operations. Barley is used world-wide for animal feed, brewing and human food. Grain is used for the preparation of malt which has many industrial uses. It is used in the field of food, beverages, breweries, distilleries and pharmaceuticals. It is also used as the basic raw material for malted foods like bournvita, horlicks, maltova and protein based food products. Barley is also consumed by the humans in many forms like chapatti, sattu (flour from roasted barley grains), dalia, halwa, and barley pops. Barley is highly digestible compared to wheat because of low gluten content. Barley chapatti can be easily digested even by the persons suffering from stomach ailment. In developing countries, cereal grains including barley are the primary and less expensive sources of carbohydrates (starch and sugars), lipids and minerals which are required for various cellular and body functions. In India almost 80 % of the total barley produced is consumed as cattle feed and rest by the poor classes as flour for chapatti making or as sattu (Anonymous 2006). Therefore, emphasis has been laid on the quality evaluation of these nutritional characteristics for assessing their suitability for human consumption (MacGregor and Bhatty 1993). In fact, barley meals and fractions are now gaining renewed interest as ingredients for the production of functional foods (pastas, baked products) (Marconi and Cubadda 2000), due to their concentration of bioactive compounds, such as β -glucans and tocopherols (Peterson 1994). For this purpose, the aim of this work was to investigate (a) the effect of processing conditions on the quality characteristics of barley chips (b) the effect of salt concentration and packaging material on the quality and stability of the product during 180 days of storage under ambient conditions.

Materials and methods

Raw materials widely grown landrace barley (Karan) was obtained from Doda area of Jammu and Kashmir, India. Lime, vegetable oil and salt were procured from local markets. The different physico-chemical characteristics of the procured barley studied were 1,000 kernel weight (AACC 2000), Hectolitre weight (AACC 2000), density (Bhattacharya et al. 1972), moisture content (AACC 2000), fat content (AOAC 2000), amylose content (Hoover, and Ratnayake 2001), and amylopectin (Hoover, and Ratnayake 2001).

Preparation of barley chips

The present investigation, comprised of two experiments was carried out in the division of Post Harvest Technology,

SKUAST- K, Shalimar, J & K, India. In the first experiment, to optimize process for the production of barley chips, two treatments of lime (0.5 % and 1 %), three treatments of frying temperature (170, 180 and 190 °C) and three treatments of frying time (60, 70 and 80 s) which make 18 treatment combination were tested. Barley grains were cooked and steeped for overnight. Grinding was done to prepare masa which was fried after sheeting and cutting. The best treatment combination w.r.t lime concentration, frying temperature and frying time selected on the basis of sensory evaluation was used for further studies. In the second experiment, effect of salt concentration (1 and 2 %) and packaging material (polyethylene and aluminium based laminate) on the quality and stability of the product, were studied

Physico-chemical characteristics of barley chips

The effect of lime concentrations, frying temperatures and frying time on various physico-chemical characteristics of fresh barley chips was studied. Shelf life studies for barley chips packed in polyethylene and aluminium based laminated bags were conducted at room temperature and the products were evaluated for 6 months at 0, 60, 120 and 180 days using organoleptic as well as physico-chemical analytical methods. Moisture content was determined by drying pre-weighed samples (2 g) in hot air oven at 130 ± 1 °C for an hour and moisture content in percent was calculated from loss of weight (AACC 2000). Fat content was estimated by extracting weighed sample (5 g) with petroleum ether (boiling point 60–80 °C) in a soxhlet apparatus for 16 h. The extract containing fat and petroleum ether was evaporated over steam bath and dried in an oven at low temperature (50 °C), weighed and percent fat was calculated (AOAC 2000). The amylose content and amylopectin was determined by the method prescribed by Hoover and Ratnayake (Hoover, and Ratnayake 2001). Colour was determined by using Colour Tec-PCM/PSM (28 centre street Clinton, New Jersey) colorimeter. While as fracture force test was conducted on chips using a texture analyser (TA-X T2, Stable Micro system, survey, UK).

Sensory evaluation

The sensory evaluation of the fresh and stored products was conducted by a panel of 10 semi-trained judges. Each sample was evaluated for colour, texture, flavour and overall acceptability on 5-point scale (where 5 = excellent, 4 = very good, 3 = good, 2 = satisfactory and 1 = poor).

Statistical analysis Experiments were carried out in triplicate and data was analyzed using design factorial in CRD as suggested by Snedecor and Cochran (1967).

Results and discussion

Physico-chemical fresh barley The average thousand kernel weight, hectolitre weight and density recorded in procured barley were 43.40 g, 66.80 kg/hl 0.23 g/cm³ respectively. While as the moisture and fat content found was 13.25, 1.97, per cent respectively. The grain also contains 25.39 % amylose and 74.61 % amylopectin. Similar findings were reported for barley grain composition by (Sidhu et al. 1990), (Yadav et al. 2000), Yadav et al. (2000), Andersson et al. (1999), Baik et al. (2004). Sidhu et al. (1990) however reported higher hectolitre weight 81.2 kg/hl. Since the amylose content recorded in grain is greater than 10 % and less than 35 %, so it may be categorised as normal amylose barley.

Physico-chemical characteristics of barley chips

Moisture (%) The effect of lime concentrations, frying temperature and frying time on moisture per cent of barley chips shown in Table 1 reveals that the lime concentration significantly influenced the moisture per cent of chips. Mean moisture content of chips with 0.5 % lime treatment was significantly lower (2.50 %) compared to chips with 1 % lime treatment (2.66 %). The data further reveals that frying temperature significantly influenced the moisture content of chips. There was a decrease in moisture content of chips as the frying temperature was increased from 170 to 190 °C. Highest mean moisture content (2.90 %) was observed at 170 °C and lowest (2.27 %) at 190 °C which significantly differ with each other and with mean moisture content (2.58 %) at 180 °C frying temperature.

Table 1 Effect of lime, frying temperature and frying time on moisture content (%) of barley chips

Lime concentration (%)	Frying temperature (°C)	Frying time (seconds)			Mean	Frying temperature mean
		60	70	80		
0.5	170	2.90	2.80	2.70	2.80	F ₁ =2.90
	180	2.60	2.50	2.40	2.50	
	190	2.30	2.20	2.10	2.20	
Mean		2.60	2.50	2.40	2.50	F ₂ =2.58
1	170	3.10	3.00	2.90	3.00	
	180	2.75	2.64	2.55	2.64	
	190	2.45	2.35	2.20	2.33	F ₃ =2.27
Mean		2.77	2.67	2.55	2.66	
Frying time mean		2.68	2.58	2.48		

CD_(p≤0.05)

Frying temperature = 0.006; Frying temperature × lime = 0.010

Time = 0.006; Time × lime = 0.010

Lime = 0.005; Frying temperature × time × lime = 0.030

Frying temperature × time = 0.014

(n=3)

The data given in Table 1 also reveals that frying time significantly influenced the moisture content per cent of chips as the frying time increased from 60 to 80 s. Highest mean moisture content (2.68 %) was recorded at 60 s and lowest (2.48 %) at 80 s which significantly differ with each other and with mean moisture content (2.58 %) at 70 s frying time. All the interactions were statistically significant with respect to decrease in moisture content during frying. Similar results were observed by Moreira et al. (1997), Kawas and Moreira (2001), in tortilla chips. Increase in moisture content with an increase in lime concentration is due to increase in the hull permeability of grain for water during nixtamalization. And decrease in moisture content of chips with increase in frying temperature and frying time is due to replacement of moisture by frying oil.

The chips prepared with two different levels of salt revealed significant increase in mean moisture content during 180 days of storage (Tables 7 and 8). The salt application showed a significant effect on moisture content of chips. The chips treated with 2 % salt had higher mean moisture content than chips treated with 1 % salt. Further, mean moisture content was found higher in the chips packed in polyethylene compared to those packed in aluminium based laminate. All the interactions were statistically significant (Table 9). The increase in moisture content may be attributed to moisture absorbed from the external environment in polyethylene and due to chemical reactions such as oxidative breakdown. This was in accordance with the findings of Mir and Nath (2000) in mango bar.

Fat (%) Table 2 reveals that barley chips showed a significant increase in the mean fat per cent during frying. It was observed that chips with 1 % lime treatment had higher mean fat (32.15 %) while that with 0.5 % lime treatment recorded lower (30.82 %). It was further observed that there was significant effect of frying temperature on fat content of chips. Chips fried at 190 °C had highest mean fat (31.94 %) while those fried at 170 °C recorded lowest (31.03 %). It was also observed that frying time had significant effect on fat content of chips. Those chips fried for 80 s recorded highest mean fat (31.64 %) while those fried for 60 s recorded lowest (31.33 %). All the interactions were found statistically significant. The results are in conformity with those recorded by Rahman and Uddin (2008) in papads and Krokida et al. (2000) in French fries. Increase in fat content with an increase in lime concentration is due to increase in the absorption of water during nixtamalization and then replacement of water by oil during frying. Further, the increase in fat content of chips with an increase in frying temperature and frying time is due to replacement of moisture by frying

Table 2 Effect of lime, frying temperature and frying time on fat content (%) of barley chips

Lime concentration (%)	Frying temperature (°C)	Frying time (seconds)			Mean	Frying temperature mean
		60	70	80		
0.5	170	30.31	30.41	30.55	30.42	$F_1=31.03$
	180	30.67	30.80	30.96	30.81	
	190	31.12	31.24	31.33	31.23	
Mean		30.70	30.82	30.95	30.82	$F_2=31.50$
	170	31.45	31.63	31.80	31.63	
	180	31.97	32.21	32.35	32.18	
Mean		32.47	32.63	32.86	32.65	$F_3=31.94$
	190	31.96	32.16	32.34	32.15	
Frying time mean		31.33	31.49	31.64		

CD($p \leq 0.05$)Frying temperature = 0.009; Frying temperature $\times$ lime = 0.014Time = 0.009; Time $\times$ lime = 0.014Lime = 0.007; Frying temperature $\times$ time $\times$ lime = 0.043Frying temperature $\times$ time = 0.020

(n=3)

oil. As the moisture content decreases, the chips become crunchier, thus resulting in desired product texture.

Chips prepared with two different levels of salt showed significant effect on fat content (Tables 7 and 8). Chips with 1 % salt had higher mean fat content than those with 2 % salt. Significant decrease in mean fat content was observed for all the samples of chips prepared with two different

Table 4 Effect of lime, frying temperature and frying time on amylopectin content (%) of barley chips

Lime concentration (%)	Frying temperature (°C)	Frying time (seconds)			Mean	Frying temperature mean
		60	70	80		
0.5	170	72.83	72.49	71.99	72.44	$F_1=71.35$
	180	71.64	71.25	70.92	71.27	
	190	70.55	70.17	69.88	70.20	
Mean		71.67	71.30	70.93	71.30	$F_2=70.23$
	170	70.56	70.22	69.98	70.25	
	180	69.68	69.13	68.77	69.19	
Mean		68.31	67.87	67.57	67.92	$F_3=69.06$
	190	69.52	69.07	68.77	69.12	
Frying time mean		70.60	70.19	69.85		

CD($p \leq 0.05$)Frying temperature = 0.009; Frying temperature $\times$ lime = 0.014Time = 0.009; Time $\times$ lime = 0.014Lime = 0.007; Frying temperature $\times$ time $\times$ lime = 0.043Frying temperature $\times$ time = 0.020

(n=3)

levels of salt during 180 days of storage. Chips packed in aluminium based laminate showed higher mean fat content than those packed in polyethylene. All the interactions were statistically significant (Table 9). The decrease in fat content during storage may be due to oxidation of fatty acids. The results are in consonance with that of Naik et al. (2007) in wheat pretzels.

Table 3 Effect of lime, frying temperature and frying time on amylose content (%) of barley chips

Lime concentration (%)	Frying temperature (°C)	Frying time (seconds)			Mean	Frying temperature mean
		60	70	80		
0.5	170	27.16	27.50	28.00	27.55	$F_1=28.65$
	180	28.35	28.74	29.07	28.72	
	190	29.44	29.82	30.11	29.79	
Mean		28.32	28.69	29.06	28.69	$F_2=29.76$
	170	29.43	29.77	30.01	29.74	
	180	30.31	30.86	31.22	30.80	
Mean		31.68	32.12	32.43	32.08	$F_3=30.94$
	190	30.47	30.92	31.22	30.87	
Frying time mean		29.39	29.80	30.93		

CD($p \leq 0.05$)Frying temperature = 0.009; Frying temperature $\times$ lime = 0.014Time = 0.009; Time $\times$ lime = 0.014Lime = 0.007; Frying temperature $\times$ time $\times$ lime = 0.043Frying temperature $\times$ time = 0.020

(n=3)

Table 5 Effect of lime, frying temperature and frying time on instrumental colour score (pt) of barley chips

Lime concentration (%)	Frying temperature (°C)	Frying time (seconds)			Mean	Frying temperature mean
		60	70	80		
0.5	170	54.92	55.07	56.12	55.37	$F_1=53.88$
	180	52.40	52.80	53.55	52.92	
	190	51.72	52.36	52.73	52.27	
Mean		53.01	53.41	54.13	49.08	$F_2=50.74$
	170	51.43	51.71	54.03	52.39	
	180	47.22	49.13	49.33	48.56	
Mean		45.94	46.09	47.00	46.35	$F_3=49.31$
	190	48.29	48.98	50.12	53.52	
Frying time mean		50.60	51.19	52.13		

CD($p \leq 0.05$)Frying temperature = 0.270; Frying temperature $\times$ lime = NSTime = 0.342; Time $\times$ lime = 0.755Lime = 0.342; Frying temperature $\times$ time $\times$ lime = NSFrying temperature $\times$ time = 0.543

(n=3)

Table 6 Effect of lime, frying temperature and frying time on instrumental texture of barley chips

Lime concentration (%)	Frying temperature (°C)	Frying time (seconds)			Mean	Frying temperature mean
		60	70	80		
0.5	170	2.83	2.67	2.50	2.66	$F_1=2.61$
	180	2.33	2.15	1.98	2.14	
	190	1.74	1.55	1.37	1.55	
Mean		2.30	2.12	1.95	2.12	$F_2=2.06$
	170	2.72	2.56	2.41	2.56	
	180	2.23	2.02	1.83	2.02	
Mean		1.61	1.44	1.26	1.43	$F_3=1.49$
	170	2.72	2.56	2.41	2.56	
	180	2.23	2.02	1.83	2.02	
Frying time mean		2.24	2.06	1.89	2.00	

CD_(p≤0.05)

Frying temperature = 0.006; Frying temperature × lime = 0.014

Time = 0.005; Time × lime = NS

Lime = 0.006; Frying temperature × time × lime = 0.030

Frying temperature × time = 0.003

(n=3)

Amylose (%) The data in Table 3 reveals that lime concentrations, frying temperature and frying time had a significant effect on the amylose content of barley chips. Higher mean amylose content (30.87 %) was recorded in chips treated with 1 % lime while lower (28.69 %) in chips treated with 0.5 % lime. It was further observed that highest mean amylose content (30.94 %) was recorded in chips fried at 190 °C frying temperature while lowest (28.65 %) for 170 °C. It was also observed that chips fried for 80 s recorded highest mean amylose content (30.93 %) while those fried for 60 s recorded lowest mean amylose content

(29.39 %). Similar findings have been reported by Sinha and Sharada (1992) in maize roti and Li et al. (2004), during their study on structural changes in waxy, normal and high amylose starch granules on heating. Amylose content of chips increased with an increase in lime concentration, frying time and temperature. This may be due to conversion of amylopectin to amylose during nixtamalization and frying. All the interactions were found statistically significant.

Salt had a non-significant effect on the amylose content of the chips. The mean amylose content of the chips increased significantly during 180 days of storage (Tables 7 and 8). Chips packed in polyethylene recorded higher mean amylose content than those packed in aluminium based laminates. All the interactions except (package × storage) were found statistically non-significant (Table 9). Similar findings were obtained by Kumari et al. (2007) in cereal-pulse based ready to eat commercial products.

Amylopectin (%) The data presented in Table 4 indicates significant decrease in amylopectin per cent in a barley chips. The mean amylopectin content of chips with 0.5 % lime treatment was recorded significantly higher (71.30 %) compared to chips with 1 % lime treatment (69.12 %). Effect of frying temperature was found significant. Highest mean amylopectin content (71.35 %) was found in chips fried at 170 °C frying temperature while lowest (69.06 %) was recorded in those chips fried at 190 °C. The effect of frying time was also found significant. Highest mean amylopectin content (70.60 %) was recorded in chips fried for 60 s and lowest (69.85 %) in chips fried for 80 s. All the interactions were found statistically significant. Amylopectin content of chips decreased with an increase in lime concentration, frying time and frying temperature. This

Table 7 Effect of salt (1 %) and packaging material on quality attributes of barley chips during storage

Physico-chemical characteristics	Storage period (Days)							
	0		60		120		180	
	P1	P2	P1	P2	P1	P2	P1	P2
Moisture (%)	2.20	2.20	2.28	2.24	2.36	2.27	2.43	2.30
Fat (%)	32.86	32.86	32.84	32.84	32.82	32.82	32.70	32.81
Amylose content (%)	32.41	32.45	33.01	33.73	35.45	34.50	36.60	35.25
Amylopectin (%)	67.58	67.58	65.98	66.26	64.54	65.49	63.39	64.74
Colour	60.05	66.95	59.88	66.56	59.80	65.87	59.67	59.65
Texture	1.25	1.25	1.37	1.31	1.50	1.36	1.59	1.42
Sensory characteristics								
Colour	3.60	3.69	3.50	3.60	3.30	3.40	3.15	3.19
Texture	3.85	3.86	3.65	3.71	3.30	3.50	3.01	3.30
Flavour	3.62	3.61	3.41	3.51	3.21	3.31	2.91	3.01
Overall acceptability	3.72	3.72	3.52	3.61	3.27	3.40	2.94	3.16

n=3

P1 = Polyethylene

P2 = Aluminium based laminate

Table 8 Effect of salt (2 %) and packaging material on quality attributes of barley chips during storage

	Physico-chemical characteristics	Storage period (Days)							
		0		60		120		180	
		P1	P2	P1	P2	P1	P2	P1	P2
<i>n</i> =3 P1 = Polyethylene P2 = Aluminium based laminate	Moisture (%)	2.22	2.22	2.32	2.25	2.41	2.29	2.51	2.33
	Fat (%)	32.84	32.84	32.82	32.82	32.70	32.80	32.60	32.78
	Amylose content (%)	32.40	32.41	34.05	33.74	35.47	34.51	36.67	35.27
	Amylopectin (%)	67.59	67.58	65.94	66.25	64.52	65.48	63.32	65.09
	Instrumental Colour	64.75	67.12	63.12	66.42	62.05	66.37	61.26	61.30
	Instrumental Texture	1.26	1.26	1.41	1.34	1.53	1.40	1.55	1.47
	Sensory characteristics								
	Colour	3.90	3.70	3.59	3.65	3.39	3.49	3.10	3.29
	Texture	3.80	3.81	3.56	3.61	3.21	3.41	2.91	3.16
	Flavour	3.76	3.76	3.51	3.56	3.31	3.41	3.01	3.21
	Overall acceptability	3.82	3.83	3.55	3.63	3.30	3.44	3.00	3.22

may be due to conversion of amylopectin to amylose and simple sugars during nixtamalization and frying.

Chips prepared with different levels of salt revealed non-significant effect on amylopectin content of the chips (Tables 8 and 9). Significant decrease was observed in amylopectin content of chips during 180 days of storage. Package showed a significant effect on amylopectin content of chips. Chips packed in aluminium based laminates recorded higher mean amylopectin content than those packed in polyethylene. All the interactions except (package $\times$ storage) were found statistically non-significant (Table 9). The results are in conformity with those of Baypoli et al. (2002) in maize tortillas.

Colour The data in Table 5 indicates that lime concentrations, frying temperature and frying time had a significant effect on the colour of barley chips. Higher mean colour

difference i.e. ΔE (53.52) was recorded in chips treated with 1 % lime while chips with 0.5 % lime showed lower (49.08) mean colour difference (ΔE). It was further observed that chips fried at 190 °C recorded highest mean colour difference i.e. ΔE (53.88) while those fried at 170 °C recorded lowest (49.31) mean colour difference (ΔE). The data also indicates that chips fried for 80 s recorded highest mean colour difference (52.13) and those fried for 60 s recorded lowest (50.60). Similar findings have been reported by Dedeh et al. (2004) in nixtamalized maize and Pedreschi et al. (2005) in fried potato slices. Colour difference (ΔE) increased with an increase in lime concentration, frying temperature and frying time. This may be due to absorption and retention of lime by the nixtamalized grain and due to non-enzymatic browning during frying. All the interactions except (lime $\times$ frying time) and (lime $\times$ frying temperature $\times$ frying time) were found statistically significant.

Table 9 $CD_{(p \leq 0.05)}$ values of salt, package, storage and their interactions for different quality attributes of barley chips

Physico-chemical characteristics	$CD_{(p \leq 0.05)}$						
	Salt	Package	Storage	Salt $\times$ Package	Salt $\times$ storage	Package $\times$ storage	Salt $\times$ Package $\times$ storage
Moisture (%)	0.005	0.005	0.008	0.008	0.014	0.014	0.030
Fat (%)	0.005	0.005	0.008	0.008	0.014	0.014	0.030
Amylose content (%)	NS	0.264	0.406	NS	NS	0.691	NS
Amylopectin (%)	NS	0.10	0.15	NS	NS	0.26	NS
Instrumental Colour	NS	1.885	2.90	NS	NS	NS	NS
Instrumental Texture	0.006	0.006	0.009	NS	0.015	0.015	NS
Sensory characteristics	$CD_{(p \leq 0.05)}$						
Colour	NS	NS	0.139	NS	NS	NS	NS
Texture	0.005	0.005	0.007	0.007	0.011	0.11	0.015
Flavour	0.005	0.005	0.007	0.007	0.011	0.011	0.015
Overall acceptability	0.003	0.003	0.0047	NS	0.007	0.007	NS

Table 10 Effect of lime, frying temperature and frying time on sensory characteristics of barley chips

Lime concentration (%)	Frying temperature (°C)	Colour			Texture			Flavour			Overall acceptability		
		Frying time (seconds)			Frying time (seconds)			Frying time (seconds)			Frying time (seconds)		
		60	70	80	60	70	80	60	70	80	60	70	80
0.5	170	2.61	2.71	2.81	2.46	2.56	2.66	2.41	2.51	2.61	2.49	2.59	2.69
	180	2.91	3.01	3.11	2.75	2.85	2.96	2.71	2.81	2.91	2.79	2.89	2.99
	190	3.24	3.33	3.44	3.11	3.31	3.40	3.00	3.10	3.21	3.1	3.25	3.34
Mean		2.92	3.02	3.12	2.77	2.91	3.00	2.71	2.81	2.91	2.80	2.91	3.01
1	170	2.81	2.91	3.01	2.55	2.66	2.75	2.51	2.61	2.71	2.62	2.72	2.82
	180	3.11	3.21	3.31	2.86	2.95	3.16	2.81	2.91	3.00	2.92	3.02	3.16
	190	3.39	3.51	3.59	3.31	3.51	3.70	3.10	3.21	3.36	3.27	3.41	3.55
Mean		3.10	3.21	3.30	2.91	3.04	3.21	2.81	2.91	3.02	2.94	3.05	3.18
Frying time mean		3.01	3.11	3.21	2.84	2.97	3.11	2.76	2.86	2.96	2.87	2.98	3.09

Colour			Texture			Flavour			Overall acceptability		
CD _(p<0.05)			CD _(p<0.05)			CD _(p<0.05)			CD _(p<0.05)		
Frying temperature	=	0.02;	Frying temperature	=	0.006;	Frying temperature	=	0.006;	Frying temperature	=	0.009
Time	=	0.02;	Time	=	0.006;	Time	=	0.006;	Time	=	0.009
Lime	=	0.015;	Lime	=	0.005;	Lime	=	0.005;	Lime	=	0.008
Frying temperature x time	=	NS;	Frying temperature x time	=	0.01;	Frying temperature x time	=	0.01;	Frying temperature x time	=	0.016
Frying temperature x lime	=	NS;	Frying temperature x lime	=	0.008;	Frying temperature x lime	=	0.008;	Frying temperature x lime	=	0.013
Time x lime	=	NS;	Time x lime	=	0.008;	Time x lime	=	0.008;	Time x lime	=	0.013
Frying temperature x time x lime	=	NS;	Frying temperature x time x lime	=	0.015;	Frying temperature x time x lime	=	0.015;	Frying temperature x time x lime	=	0.023

n = 3

Salt showed a non-significant effect on the colour (colour difference i.e. ΔE) of chips. The mean value of ΔE of chips showed significant decrease during 180 days of storage (Tables 7 and 8). Chips packed in aluminium based laminates recorded significantly higher mean ΔE value than those packed in polyethylene. All the interactions were found statistically non-significant (Table 9). The decrease in colour difference of chips during storage may be due to peroxidation of lipids. Similar findings were reported by Daramola and Asumni (2006) in deep-fat fried snack food.

Texture The data in Table 6 indicates that lime concentrations, frying temperature and frying time had a significant effect on the texture of barley chips. Higher mean break force (2.12 kg) was observed in chips treated with 0.5 % lime while lower (2.00 kg) was recorded in chips treated with 1 % lime. It was further observed that highest mean break force (2.61 kg) was recorded in chips fried at 170 °C frying temperature while lowest (1.49 kg) at 190 °C. The data also reveals that chips fried for 60 s had highest mean break force (2.18 kg) while those fried for 80 s had lowest (1.83 kg). The results are in conformity with that of Suderman (1983), Loewe (1993) in batter systems and Kawas and Moreira (2001) in tortilla chips. The decrease in break force with an increase in lime concentration, frying temperature and frying time may be due to strength

provided by lime absorbed during nixtamalization and loss of moisture during frying. All the interactions except (lime $\times$ frying time) were found statistically significant.

Chips prepared with two different levels of salt showed significant effect on their texture (Tables 7 and 8). Chips with 2 % salt recorded higher mean break force than those with 1 % salt. Significant increase in mean break force for chips was observed during 180 days of storage. Chips packed in polyethylene recorded significantly higher mean break force than those packed in aluminium based laminates. All the interactions except (salt $\times$ storage) and (salt $\times$ package $\times$ storage) were found statistically significant (Table 9). The increase in break force during storage may be due to increase in moisture content of chips.

Sensory evaluation The data presented in Table 10 illustrates the mean organoleptic scores for colour, texture, flavour and overall acceptability of barley chips. It is evident that lime and frying temperature had a significant effect on all the organoleptic properties studied. The chips prepared from masa treated with 1 % lime recorded highest colour, texture, flavour and overall acceptability scores than those with 0.5 % lime. Also, the highest mean scores for colour, texture, flavour and overall acceptability were noticed for chips obtained at frying temperature of 190 °C. Frying time also had a significant effect on all the organoleptic

properties studied. The chips fried for 80 s showed highest mean scores for all the organoleptic properties. The increase in colour score with frying may be due to non-enzymatic browning, while as increase in texture score was probably due to loss of moisture. These results were in consonance with those found by colour difference meter and texture analyzer.

The data depicted in 7 and 8 revealed that mean scores for colour, texture, flavour and overall acceptability of chips decreased during storage. Salt and package had a non-significant effect on colour score (Table 9). However, chips with 2 % salt showed higher mean flavour and overall acceptability scores. Whereas, chips with 1 % salt showed higher mean texture score. The effect of packaging material on texture, flavour and overall acceptability was also found significant. The chips packed in aluminium based laminates showed higher mean texture, flavour and overall acceptability scores than those packed in polyethylene. Similar findings were reported by Mir and Nath (1993) in mango bar and Akubor and Adejo (2000) in plantain chips.

Conclusion

It was concluded from the present studies that optimised process (1 % lime for nixtamalization, 190 °C frying temperature and 80 s frying time) followed by addition of 2 % salt and packaging in aluminium based laminates proved best for barley chip with respect to production, quality and storage stability.

References

- AACC (2000) Approved Methods of American Association of Cereal Chemists, 10th edn. The Association St. Paul, MN
- Akubor PI, Adejo EE (2000) Physicochemical, microbiological and sensory changes in stored plantain chips. *Plant Foods Hum Nutr* 55(27):139–146
- Andersson A, Elfverson C, Regner S, Aman P (1999) Chemical and physical characteristics of different barley samples. *J Sci Food Agric* 79:979–986
- Anonymous (2006) Barley Cultivation. Directorate of Wheat Development. Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India, New Delhi
- AOAC (2000) Official methods of analysis. Association of Official Analytical Chemists, Washington, D.C
- Baik BK, Powers J, Nguyen LT (2004) Extrusion of regular and waxy barley flours for production of expanded cereals. *Cereal Chem* 81(1):94–99
- Baypoli ONC, Burgos ECR, Torreschavez PI, Wong BR, Saldivar SOS (2002) Physicochemical changes of starch in maize tortillas during storage at room and refrigeration temperatures. *Starch-Stärke* 54(8):358–363
- Bhattacharya KR, Sowbhagya CM, Swamy YMI (1972) Some physical properties of paddy and rice and their interrelations. *J Sci Food Agric* 23:171–174
- Bhatty RS (1993) Non-malting uses of barley. *Cereal Chem* 70:397–402
- Daramola B, Asunni OA (2006) Nutrient composition and storage studies on roselle extract enriched deep fat fried snack food. *Afr J Biotechnol* 5(19):1803–1807
- Dedeh SS, Cornelius B, Sakyi-Dawson E, Afoakwa EO (2004) Effect of nixtamalization on the chemical and functional properties of maize. *Food Chem* 86:317–324
- Fox GJ (1982) Carbohydrate makeup of various barley samples. *Food Chem* 64:203–205
- Hoover K, Ratnayake M (2001) Standard method of analysis. Kalyani Publishers, New Delhi, pp 60–61
- Hough LT (1975) Crop evolution, adaptation and yield. Cambridge University Press, New York
- Kawas ML, Moreira RG (2001) Characterization of product quality attributes of tortilla chips during the frying process. *J Food Eng* 47(2):97–107
- Krokida MK, Oreopoulou V, Maroulis ZB (2000) Water loss and oil uptake as a function of frying time. *J Food Eng* 44(1):39–46
- Kumari M, Urooj A, Prasad NN (2007) Effect of storage on resistant starch and amylase content of cereal-pulse based ready-to-eat commercial products. *Food Chem* 102(4):1425–1430
- Li JH, Vasanthan T, Hoover R, Rossnagel BG (2004) Starch from hull-less barley: IV. Morphological and structural changes in waxy, normal and high-amylose starch granules during heating. *Food Res Int* 37(5):417–428
- Loewe R (1993) Role of ingredients in batter systems. *Cereal Foods World* 38:673–677
- MacGregor, Bhatti S (1993) Barley chemistry and technology. American Association Cereal Chemists, Inc., St. Paul, pp 382–384
- Marconi E, Cubadda R (2000) Composition and utilisation of barley pearling by products for making functional pastas rich in dietary fibre and β -glucans. *Cereal Chem* 77:133–139
- Mir MA, Nath N (1993) Storage changes in fortified mango bars. *J Food Sci Technol* 30:279–282
- Mir MA, Nath N (2000) Protein fortification of mango bar using soyprotein concentration and coconut powder. *J Food Sci Technol* 37:525–528
- Moreira RG, Sun X, Chen Y (1997) Factors affecting oil uptake in tortilla chips in deep fat frying. *J Food Eng* 31(4):485–498
- Naik HR, Sekhon KS, Baljit S, Kaur A, Rather AH (2007) Influence of triticales and wheat classes on pretzel quality. *J Food Sci Technol* 44(5):495–499
- Pedreschi F, Moyano P, Kaack K, Granby K (2005) Colour changes and acetylamide formation in fried potato slices. *Food Res Int* 38:1–9
- Peterson DM (1994) Barley tocals: effects of milling, malting and mashing. *Cereal Chem* 71:42–44
- Poehlman JM (1985) Adaptation and distribution. In: Rasmusson DC (ed) Barley, ASA monogr. 26. American Society of Agronomists, Madison, WI, pp 1–17
- Preece S, Mackenzie J (1952) Chemical composition of barley varieties and their malting quality. US Patent Application, US 1526357
- Rahman MM, Uddin MB (2008) Effect of frying conditions on moisture and fat of papads. *Int J Sustain Crop Prod* 3(2):16–21
- Santosh S (2012) Grain and feed annual India. USDA Foreign Agricultural Service, Grain Report-Global Agricultural Information Network. Report No. 3012, pp. 20

- Sidhu JS, Harinder K, Kaur A, Ram MB (1990) Functional and chapatti making properties of hull-less barley supplemented wheat flour. *J Food Sci Technol* 27(5):311–313
- Sinha R, Sharada D (1992) Chemical characteristics of maize grains and their relationship to roti quality. *J Food Sci Technol* 29:243–244
- Snedecor GW, Cochran WG (1967) Statistical methods. The Iowa State University Press, USA, pp 339–377
- Suderman DR (1983) *Batter and breadmaking technology*. AVI Publishing Company, Inc, Westport
- Wang L, Behr SR, Rosemary K (1997) Classification of barley genotypes and their nutritional importance. *Nutr Res* 17:77–80
- Yadav SK, Luthra YP, Sood DR, Singh D (2000) Carbohydrate make up of huskey barley. *Starch-Starke* 52(4):125–128