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DEVELOPMENT OF FORMULATION FOR ROLLABLE AND QUALITY MAIZE *CHAPATTI*

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ABSTRACT

Maize *chapatti* has vast limitations over wheat *chapatti.* It has a harder and dryer texture; a coarser appearance (cracks at ends); requires more skillful efforts thus reducing its acceptability and preparation by today's generation. This study was carried out to monitor the effect of the incorporation of additives on the preparation technology, sensory studies, quality, and shelf life of *chapatti*. The investigation found to be useful at an optimum level of xanthan gum (0.75%), guar gum (0.75%), whey protein concentrate (5%), and potato starch (5%) incorporation in maize flour for improving the preparation technology and quality of maize *chapatti*. Mass sensory scores were also found to be very good for developed formulation in terms of rollability and taste of chapatti.

Keywords: Chapatti, Guar gum, Rollable, Whey protein concentrate, Xanthan gum

Maize is cultivated throughout India. Since maize has both spring and winter varieties, it can be relied upon for its availability throughout the year. Although maize is the gold of Punjab, still its distribution is not limited as it is available in all other states of India. *Chapatti* is the staple meal of central and northern India. 'Makki ki roti' along with 'Sarson ka saag' is considered the principal meal of Punjab and is mostly relished in winter. Over time, maize *chapatti* consumption has been limited. This can be attributed to a busy lifestyle, urbanization, professional women, and economic considerations. Despite these, the preparation of maize *chapatti* requires more skill and effort as compared to wheat *chapatti* mainly due to the absence of gluten protein which contributes binding and elasticity to it. Several studies have reported that hydrocolloids have properties that improve the elasticity, flexibility, and overall texture and quality of the finished product. They can act as a gluten substitute (Lazaridou *et al.,* 2007), can add flexibility, and function as fat replacers, water binders, texturizers, and adhesives (Gurkin, 2002). Besides hydrocolloids, potato starch also exhibits the highest swelling power and gives the highest viscosity of pasting properties as compared to all other commercial starches (Mitch, 1984). Moreover, the protein forms a continuous protein phase which is critical for obtaining the improvement in the quality of gluten-free bread (Moore *et al.,* 2004).

Nevertheless, no study has been reported on the addition of hydrocolloids such as xanthan, guar gum, whey protein concentrate, and potato starch in maize flour for *chapatti* preparation. The preparation of maize *chapatti* is the biggest technological challenge that needs to be resolved soon. Thus, the investigation would help to commercialize the maize formulation under the name 'convenience maize *chapatti* formulation' and would be a boon for celiac patients. A study was carried out to monitor the effect of additives on the preparation technology, quality, sensory study, and shelf life of maize *chapatti*.

MATERIALS AND METHODS

Materials

Maize varieties namely, PMH1, JL3459, and Buland were procured from Director of seeds, Punjab Agricultural University, Ludhiana. Additives: xanthan gum and guar gum were bought from Alliance global, New Delhi; potato starch from S.D Fine Chem. Ltd, Biosar-401506, India; whey protein concentrate was obtained from Mahaan Protein Ltd, New Delhi-110001, Delhi, India, and salt was procured from a local market.

Physical properties of grains

Different varieties of maize grains were evaluated for physical properties namely 1000 kernel weight (AACC 2000), force to rupture (AACC 2000), bulk density (Mohsenin 1970) and color using Hunter colorimeter.

Milling

Each maize variety was milled into varied particle size 60, 70, and 80 µm using B1, B2, and B3 sieve in domestic 'attahakki'.

Chemical analysis of flour

The chemical compositions of all three varieties

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of maize flour were analyzed. Standard AACC (2000) procedure was followed for determination of moisture content (44.15 A), protein content (46-11 A), fat (Soxtech apparatus), ash (08-01), crude fiber (Fibertech), and starch on a wet basis.

Incorporation of additives

The level of additives of concentration ranging from xanthan gum (XG) 0.25-1%, guar gum (GG) 0.25-1%, whey protein concentrate (WPC) 5-15%, and potato starch (PS) 5-10% were incorporated in maize flour.

Preparation of maize *chapatti*

The *chapatti* was prepared using the method described by Rao *et al.* (1986). *Chapatti* of varied particle size flour of each variety was prepared. Standard particle fraction and best cultivars opted for the incorporation of additives followed by the preparation of *chapatti*. An optimum level of water for dough development was recorded. Dough was allowed to rest for 20-30 minutes. A dough boll of 60 g each was sheeted to a circular smooth surface (13.5 cm diameter) with rolling pin. After that, *chapatti* was baked on a hot griddle with turnings until brown spots appeared on it. The puffing and roll-ability attributes were also documented.

Sensory data

The 'chapattis' were monitored by a panel of a minimum of ten semi-trained judges on nine-point hedonic scale in context to appearance, colour, aroma, texture, and overall acceptability (Larmond, 1970).

Texture analysis

The hardness/chewiness of *chapatti* was analyzed by Stable Microsystem Texture Analyser Model (TA-H di England) using the following settings:

Parameter	Maize *chapatti*
Test	TPA
Probe	75 mm Compression Platen
Pre-test speed	2mm/s
Test speed	1 mm/s
Post-test speed	2mm/s
Distance	50% Strain
Acquisition Rate	200 points per second
Force	453g

Shelf life studies of *chapattis*

Chapattis were packed in low-density polyethylene (LDPE-150 gauge) and stored under ambient conditions for shelf life studies. 'Chapattis' were evaluated on basis of free fatty acid (AACC, 2000), peroxide value (AOAC, 2000), moisture, pH (Mettler Toledo pH meter) and microbiological analysis (AACC, 2000, Nutrient Agar base).

Consumer evaluation

Selected maize formulation containing the best level of all additives was given to 50 consumers having different age groups, economic statuses etc.

Statistical analysis

The data collected in different investigations were analyzed with factorial design in CRD using software CPCS-1(Gomez and Gomez, 2010).

RESULTS AND DISCUSSION

Physicochemical properties of different maize varieties

The physicochemical properties of different maize varieties were assessed to determine their quality and nutritional value. Physicochemical characteristics of maize varieties such as PMH1, Buland, and JL3459 are elucidated in Table 1. Thousand kernel weight of maize varieties ranged between 197 g to 312.67 g. Bulk density of PMH1 and JL3459 was found to be same (0.80 g/ml) but Buland had a minimum bulk density (0.76 g/ml). The L* (indicator of lightness), b*(indicator of blueness and yellowness) value of colour was observed maximum in JL3459 (84.84 and 24.21), respectively. The highest a* (indicator of redness and greenness) 1.35 was observed in Buland. Similar findings of corn grits colour were reported by Jamin and Flores (1998). Among the three varieties, force to rupture was highest in PMH1 (68.54 kg) followed by Buland (68.42 kg) and JL3459 (67.20 kg). Maize grains had moisture content ranging between 9.53 and 16.03 per cent. The values observed for protein, starch and fat content were from 10.36 to 11.30 per cent, 64.66 to 67.70 per cent and 4.97-5.13 per cent, respectively. The fiber and ash contents of maize varieties were obtained from 2.05 to 2.38 per cent and 1.34 to 1.52 per cent, respectively. The observed chemical composition of maize varieties was in good agreement with the previous study (Thakur *et al.,* 2015).

Effect of additives on maize *chapatti* making quality and sensory scores of PMH1

Statistically significant variations were observed in the water absorption capacity of maize flour containing additives is documented in Table 2. On increasing the level of xanthan gum significant increase in the water absorption capacity of flour was noticed. The effect has been attributed to OH group in hydrocolloids which caused more water binding through hydrogen bonding. Rollability was found to be good when the level of xanthan gum >0.5%. The reported attributes like elasticity, binding and adhesiveness could have

Table 1. Physico-chemical composition of maize varieties (Average value± SD)

		Variety	
Characteristic	**PMH1**	**JL3459**	**Buland**
Thousand kernel weight (g)	312.67±2.08	197.00±1.00	216.33±1.53
Bulk density (g/ml)	0.80±0.00	0.80±0.00	0.76±0.01
Colour L*	83.55	84.84	19.77
a*	-0.25	0.28	1.35
b*	23.01	24.21	24.04
Force to rupture (kg)	68.54±1.00	67.20±1.00	68.42±1.00
Moisture (%)	9.53±0.11	16.03±0.31	11.48±0.50
Protein (%)	10.65±0.05	11.30±0.38	10.36±0.26
Starch (%)	67.70±0.87	66.73±0.22	64.66±0.34
Fat (%)	4.97±0.53	4.97±0.12	5.13±0.65
Fibre (%)	2.05±0.32	2.22±0.45	2.38±0.13
Ash (%)	1.43±0.04	1.34±0.05	1.52±0.03

been the reason of improved dough handling and *chapatti* making quality. Sensory study explained that only up to the concentration of 0.75% achieved good scores than pure maize *chapatti*, as it contributed to enhanced softness. However, even slightly beyond the level, gumminess became more pronounced which drastically reduced the overall acceptability.

The *chapatti* with GG had more water absorption capacity than the control, moreover was positively dependent on the concentration of GG. The higher the level of GG, the better the roll-ability was observed. Shalini and Laxmi (2007) cited that *chapatti* with GG

Table 2. Effect of additives on *chapatti* making quality and sensory panel scores (PMH1)

Additive	Level (%)	Water absorption (%)	Roll-ability	Puffing	Appearance	Texture	Colour	Aroma	Overall acceptability
					(max.9)				
Control	0	104.00	Poor	Poor	8.33	8.67	8.33	8.00	8.33
Xanthan gum	0.25	109.00	Fair	Poor	8.33	8.67	8.33	8.00	8.33
	0.50	116.00	Good	Good	8.33	8.67	8.67	8.00	8.50
	0.75	124.67	Good	Good	8.33	8.67	8.90	8.00	8.67
	1.00	129.67	Good	Good	8.33	7.33	7.33	8.00	7.42
CD ($p \leq 0.05$)		2.25			NS	NS	NS	NS	NS
Guar gum	0.25	104.00	Fair	Good	8.00	8.67	8.33	8.00	8.17
	0.5	108.67	Fair	Good	8.33	8.67	8.33	8.00	8.58
	0.75	110.67	Good	Good	8.67	8.67	8.33	8.00	8.67
	1.00	112.00	Good	Good	8.33	7.33	7.33	8.00	7.58
CD ($p \leq 0.05$)		2.66			NS	NS	NS	NS	NS
Whey protein concentrate	5	99.00	Good	Good	8.33	8.67	8.33	8.00	8.50
	10	97.00	Good	Good	8.33	7.67	6.33	8.00	7.58
	15	89.00	Good	Good	6.67	7.33	6.33	8.00	7.25
CD ($p \leq 0.05$)		1.883			NS	1.09	1.09	NS	0.96
Potato starch	5	113.67	Good	Poor	8.33	7.67	6.67	8.00	7.00
	10	108.67	Good	Poor	6.33	6.33	6.33	8.00	6.17
CD ($p \leq 0.05$)		2.75			1.15	1.15	1.15	NS	0.80

CD = Critical difference at 5% level
NS = Non significant

up to 0.75 % concentration gave better sheeting while beyond that level *chapatti* became sticky due to dilution of gluten content. Puffing was seen at all concentrations of GG. The *chapatti* with 0.75 per cent GG scored the highest in regard to appearance and texture whereas beyond this there was a reduction in scores which might have been due to the pronounced effect at higher concentrations that leads to gumminess and stickiness in chewability.

Water absorption was dependent on the inclusion concentration of WPC; the higher the WPC more was water absorption. The addition of WPC (5%) gave good roll-ability and was puffed as compared to the control. Both former attributes remained good at all concentrations of WPC.

With an increase in the concentration of WPC, there was a decrease in sensory scores noted. This has probably resulted due to reduced water absorption of dough which consequently hardened the texture. In line with an earlier study that reported that WPC imparts optimum dough handling and processing (Onderi *et al.,* 2013) and provides maximum extension due to a strengthened protein network (Kenny *et al.*, 2001). Hence, on basis of *chapatti* making quality and sensory scores optimum level was 5 % of WPC was selected.

The water absorption decreased significantly as the concentration of potato starch increased. Rollability was optimum with a rolling pin at 5 per cent level of potato starch. However, puffing in *chapatti* with potato starch was not observed. Texture and color scores reduced significantly with an increased inclusion percentage of PS; however, the aroma was not affected. This could be attributed to reduced moisture in the dough with PS resulting in hardness, dryness, and surface whiteness of *chapatti*.

Effect of additives on the *chapatti* - making quality and sensory scores of JL3459

The incorporation of xanthan gum affected the water absorption capacity of the dough significantly. Maize flour with xanthan gum had more water absorption capacity than without it. Moreover, water absorption capacity depended directly on the inclusion concentration of XG. Rollability improved with an increase in the concentration of XG. It may be due to the fact that elasticity contributes the better sheeting. (Gujral and Pathak, 2002). Puffing of *chapatti* is a desirable attribute and contributes softness obtained by the addition of ≥0.5 per cent XG which might have been the result of gum extensibility. The sensory study revealed that *chapatti* with XG (0.5% and 0.75%) achieved more scores than pure maize *chapatti* because of imparting softness however, at a concentration of 1per cent XG decreased overall acceptability as it pronounced gumminess flavor. Earlier findings by Onderi *et al.* (2013) have been reported which show similar results that 2% XG substituted gluten and gave sheetable pizza.

The puffing was observed in *chapatti* with >0.5 percent GG. Since puffing imparts softness thus, has the desirable attribute. Insignificant variations were observed for appearance, color, and aroma by increasing the additional concentration of GG. The *chapatti* with 0.75 percent GG was selected on basis of better rollability and good overall acceptability. As a fact, GG allows more water binding and elasticity and adhesiveness which probably are responsible for bettering the quality of *chapatti* making and overall acceptability.

Whey protein concentrate was negatively correlated with the water absorption of dough. Although the addition of WPC made *chapatti* rollable and puffed but these remained unchanged with an increase in the concentration of WPC. The minimum concentration of WPC (5%) was found to be overall acceptable by panellists but beyond the concentration, the acceptability reduced because of its hardness, dryness, and whitishness.

With the increase in the concentration of PS, there was significant reduction in the water absorption of dough. Though *chapatti* was rollable at 5 per cent and 10 per cent level of PS, however, puffing was not noticed. The concentration of PS was optimum at level 5 % as it enhanced both *chapatti*-making quality and sensory scores.

Effect of incorporation of additives on textural properties of *chapattis* prepared from maize variety (PMH1)

The texture analyser was used for texture profile analysis and the data obtained is presented in Table 4. The effect of additives such as guar gum, xanthan gum, whey protein concentrate, and potato starch on the textural properties of ‘chapattis’ prepared from maize variety (PMH1) was analysed. The parameters obtained were hardness, adhesiveness, springiness, gumminess, cohesiveness, resilience, and chewiness. The TPA methodology gives a correlation with organoleptic analysis (Bourne, 1986). On increasing the level of guar gum, decreased hardness was observed. Shalini and Laxmi (2007) reported that an improvement in the softness of ‘chapattis’ was observed when adding some hydrocolloids at an increasing level however; guar gum gave the best result at 0.75% (w/w) in whole wheat flour. Similar results were obtained by Guardae *et al.* (2004) and Bell (1990), who observed great quality wheat bread with incorporated hydrocolloids. Adhesiveness was non-significantly

Table 3. Effect of additives on *chapatti* making quality and sensory scores (JL3459)

Additive	Level (%)	Water absorption (%)	Roll ability	Puffing	Appearance	Texture	Colour	Aroma	Overall acceptability
							(max.9)		
Control	0	100.00	Poor	Poor	8.33	8.67	8.33	8.00	8.33
Xanthan gum	0.25	102.33	Fair	Poor	8.33	8.67	8.33	8.00	8.33
	0.50	103.33	Good	Good	8.33	8.67	8.67	8.00	8.50
	0.75	105.00	Good	Good	8.33	8.67	8.90	8.00	8.67
	1.00	109.00	Good	Good	8.33	7.33	7.33	8.00	7.42
CD (0.05)		1.56			NS	NS	NS	NS	NS
Guar gum	0.25	104.00	Fair	Good	8.00	8.67	8.33	8.00	8.17
	0.5	106.33	Fair	Good	8.33	8.67	8.33	8.00	8.58
	0.75	110.33	Good	Good	8.67	8.67	8.33	8.00	8.67
	1.00	111.33	Good	Good	8.33	7.33	7.33	8.00	7.58
CD (0.05)		2.15			NS	NS	NS	NS	NS
Whey protein concentrate	5	98.33	Good	Good	8.33	8.67	8.33	8.00	8.50
	10	70.00	Good	Good	8.33	7.67	6.33	8.00	7.58
	15	79.00	Good	Good	6.67	7.33	6.33	8.00	7.25
CD (0.05)		2.37			NS	1.08	1.08	NS	0.96
Potato starch	5	98.33	Good	Poor	8.33	7.67	6.67	8.00	7.00
	10	103.00	Good	Poor	6.33	6.33	6.33	8.00	6.17
CD (0.05)		2.40			1.15	1.15	1.15	NS	0.80

CD = Critical difference at 5% level
NS = Non Significant

Table 4. Effect of incorporation of additives on textural properties of *chapattis* prepared from maize variety (PMH1

Additives	Level (%)	Hardness (N)	Adhesive-ness	Springi-ness	Gumminess (N)	Cohesive-ness	Resilience	Chewiness (N)
Control	0	189.71	-8.00	0.35	177.38	0.93	0.91	62.55
Guar gum	0.25	88.98	16.92	0.34	0.72	0.78	0.85	0.23
	0.50	89.45	-0.90	0.45	76.65	0.83	0.75	33.45
	0.75	44.20	-0.50	0.26	39.32	0.89	0.88	10.45
	1.00	13.59	-1.94	0.35	12.42	0.93	0.84	5.06
CD (0.05)		1.65	NS	0.72	2.26	0.10	0.43	1.93
Xanthan gum	0.25	1.00	0.57	87.43	ND	ND	0.63	ND
	0.5	20.70	13.48	132.96	ND	ND	0.75	ND
	0.75	29.75	0.86	190.63	ND	ND	0.75	ND
	1.00	135.38	-16.79	1167.76	0.84	-0.02	0.78	993.44
CD (0.05)		2.55	NS	2.90	1.06	0.29	0.68	2.05
Whey protein concentrate	5	73.44	-109.58	0.29	67.45	0.91	0.88	14.82
	10	121.14	-26.57	0.37	108.39	0.92	0.78	40.40
	15	1165.82	66.60	0.21	1031.53	0.88	0.81	219.36
CD (0.05)		2.11	29.40	0.54	2.47	NS	0.42	2.57
Potato starch	5	0.26	-11.31	1.44	2.00	-7.31	2.93	2.65
	10	636.91	6.56	0.35	141.49	0.92	0.82	55.04
CD (0.05)			NS	0.83	3.60	0.33	0.55	1.65

CD = Critical difference at 5% level
NS = Non Significant
ND= Not Defined

varied with increasing the addition level of guar gum in *chapattis*. Gumminess was found to be highest at 0.5 per cent level of guar gum incorporation in *chapatti*. The observation was in agreement with the finding by Ghodke *et al.* (2009) who reported that increasing guar gum concentration in wheat dough increased stickiness by absorbing water necessary for gluten cross linking. It was observed that the addition of guar gum significantly increased ($p \leq 0.05$) cohesiveness. There was statistically significant ($p \leq 0.05$) difference in chewiness of *chapatti* observed with the increased level of GG incorporation. It was matched with the previous studies that the springiness, cohesiveness, and fracturability enhanced but the hardness decreased, as the guar gum concentration increased (Zhu *et al.,* 2009). Raina *et al.* 2005 reported that when 1.5 per cent guar gum was added to pre-gelatinized rice flour, the texture of rice pasta was improved. In the present study, though the maize is free from gluten, which is essential for structure development, the binding nature of the GG might have helped to improve texture by developing firmness. It has been reported that the introduction of GG resulted in crumb structure with a more even cell size distribution in gluten-free bread (Schwarzlaff *et al.,* 1996).

The addition of xanthan gum resulted in a significant reduction in the hardness of maize chapatti as compared to the control. The increasing level of xanthan gum incorporation in *chapatti* statistically ($p \leq 0.05$) increased the hardness but significantly less than the control sample. Hager and Arendt (2013) reported that crumb hardness values of maize bread were reduced by xanthan addition. Firmness is mainly caused by retro gradation of starch gels, which is associated with syneresis of water and crystallization of amylopectin leading to harder gels (Miles *et al.,*1985). Statistically, significant variations were observed for the springiness at all level of incorporation of xanthan gum. Springiness was found to increase as the xanthan gum level increased. Gumminess was observed at 1 per cent level of xanthan gum incorporation in *a chapatti*. Chewiness was observed to be highest at 1 per cent level of xanthan gum incorporation in *chapatti*. So, addition of xanthan gum enhanced the chewiness significantly. Ho *et al.* (2013) reported that all the composite breads incorporated with banana pseudo-stem flour at 100g/kg level (B10BPF) and B10BPF added with hydrocolloid xanthan gum 8g/kg (B10BPFXG) were observed to be higher in hardness than the control during storage.

Increasing the level of WPC incorporation in *chapattis* statistically increased hardness and also compared to the control. Higher adhesiveness was found at 15 per cent of whey protein concentrate incorporation in *chapatti*. A significant increase in gumminess was observed with an increase in addition level of WPC. Insignificant variations of cohesiveness were observed with the addition of whey protein concentrate as compared to the control. On increasing the addition level of whey protein concentrate increase in chewiness of *chapatti* was observed. Gillies 1974 reported that whey acts as a tenderizer in those foods where a soft and tender structure is desired. In terms of performance, 3 per cent whey protein gluten-free dough was softest and stretched most (778.86 ± 57.37mN and 19.06 ± 1.37mm, mean elongation force and mean extension at maximum load, respectively) but was hard to work with while 1 per cent and 2 per cent whey gluten-free dough had the same performance. Upon increasing the addition concentration of WPC increased hardness. Adhesiveness was found to be maximum at 15 per cent of potato starch incorporation in *chapatti*.

The incorporation of potato starch significantly increased hardness from 0.262 to 636.91 N. Increasing the addition of potato starch in *chapatti* decreased the gumminess, cohesiveness, and chewiness got decreased. Incorporation of PS decreased gumminess, cohesiveness, and chewiness as compared to control. Jafarpour *et al.* (2012) found that adding different levels of PS into common carp surimi paste decreased the hardness and cohesiveness of the resulting surimi gel; however, this showed an inverse relationship with the concentration of added PS. Hager and Arendt (2013) reported that upon increasing the addition of potato starch adhesiveness (-11.313 to 6.563), cohesiveness (-7.308 to 0.917) and gumminess (2.004 to 141.485) increased. Starch contributed to greater adhesiveness, cohesiveness, and gumminess of examined yoghurts, whereas the hardness of potato starch was slightly lower when compared to the natural one. It is consistent with results obtained by Rawson and Marshall ()1997 who stated that exo polysaccharides produced by ropy strains contribute to a greater extent to adhesiveness but the protein matrix was more responsible for hardness.

Effect of incorporation of additives on textural properties of 'chapattis' prepared from maize variety (JL3459)

On increasing the addition of guar gum hardness got decreased (Table 5). Shalini and Laxmi (2007) reported that an improvement in the 'chapattis' softness was observed when adding some hydrocolloids at an increasing level however; guar gum gave the best result at 0.75 per cent (w/w) whole wheat flour. Similar results were obtained by Guardae *et al.* (2004) and Bell (1990) who observed great quality wheat bread with incorporated hydrocolloids. Adhesiveness varied significantly with an increase in addition level of guar gum in *chapattis.* Statistically insignificant variations of springiness were observed with increasing in addition level of guar gum. Gumminess was found to be

Table 5. Effect of incorporation of additives on textural properties of *chapattis* prepared from maize variety (JL3459)

Additive	Level (%)	Hardness (N)	Adhesiveness	Springiness	Gumminess (N)	Cohesiveness	Resilience	Chewiness (N)
Control	0	351.12	0.03	0.53	326.39	0.92	0.92	162.56
Guar gum	0.25	426.64	-7.09	0.53	387.83	0.91	0.84	213.97
	0.50	397.46	32.43	0.43	376.48	0.95	0.82	186.57
	0.75	349.10	-3.39	0.64	294.18	0.84	0.75	181.52
	1.00	262.49	-15.47	0.52	248.38	0.95	0.75	126.80
CD (0.05)		4.29	0.62	NS	5.12	0.15	0.61	1.68
Xanthan gum	0.25	4.52	1.05	12.12	ND	ND	2.22	ND
	0.5	7.88	0.44	598.84	-3.69	-0.14	0.88	-2369.58
	0.75	7.95	0.33	60.67	-4.83	-0.62	1.11	-291.22
	1.00	8.36	0.43	66.03	-1.69	-0.27	0.88	-125.36
CD (0.05)		2.00	0.11	0.58	3.65	0.12	0.42	1.63
Whey protein concentrate	5	2.77	-69.72	11.33	-43.35	-15.70	1.44	483.58
	10	3.59	-16.58	134.54	ND	ND	0.91	ND
	15	6.01	332.58	ND	ND	ND	ND	ND
CD (0.05)		2.30	3.37	2.04	4.28	0.27	0.54	1.00
Potato starch	5	0.30	-11.02	1.46	2.23	-1.33	-4.40	-3.15
	10	13.35	-39.52	60.66	-2.89	0.22	0.88	177.74
CD (0.05)		2.82	0.62	0.69	5.17	0.35	0.24	1.40

CD = Critical difference at 5% level
NS = Non Significant
ND = Not detected

maximum at 0.25 percent level of guar gum incorporation in *chapatti*. As the level of guar gum incorporation increased, statistically increased in cohesiveness was observed in comparison to control. There was statistically significant decreased in chewiness of chapatti observed with increase addition level of guar gum in *chapatti*. The present results matched with previous studies that the cohesiveness and fracturability enhanced but the hardness decreased, as the guar gum concentration increased. (Zhu *et al.* 2009). Raina *et al*. (2005) reported that when 1.5 per cent guar gum was added to pre-gelatinized rice flour, the texture of rice pasta was improved. In the present study, though the pearl millet is free from gluten, which is essential for structure development, the binding nature of the GG might have helped to improve texture by developing firmness. It has been reported that the introduction of GG resulted in crumb structure with a more even cell size distribution in gluten-free breads (Schwarzlaff *et al.* 1996).

The increasing level of xanthan gum incorporation in *chapatti* statistically increases the hardness but significantly less than the control sample. Hager and Arendt (2013) reported that crumb hardness values of maize breads were reduced by xanthan addition. Firmness is mainly caused by retrogradation of starch gels, which is associated with the syneresis of water and crystallization of amylopectin leading to harder gels (Miles *et al.* 1985). Statistically significant variations were observed for the springiness with the incorporation of xanthan gum. Addition of xanthan gum in *chapatti* reduced gumminess and chewiness as compared to control. So, the addition of xanthan gum reduced the chewiness significantly. Ho *et al.* (2013) all the composite breads incorporated with banana pseudo-stem flour at 100g/kg level (B10BPF) and B10BPF added with hydrocolloid xanthan gum 8g/kg (B10BPFXG) were observed to be higher in hardness than the control during storage.

The increasing level of WPC incorporation in *chapattis* statistically increased hardness but it was significantly less than the control. Maximum adhesiveness was found at 15 per cent level of whey protein concentrate incorporation in *chapatti*. Significant increase in gumminess was observed with an increase in the addition level of WPC. The addition of whey protein concentrate increased the chewiness of *chapatti* as compared to the control. Gillies (1974) reported that whey acts as a tenderizer in those foods where a soft and tender structure is desired. In terms of performance, 3 per cent whey protein gluten-free dough was softest and stretched most (778.86 ± 57.37mN and 19.06 ± 1.37mm, mean elongation force and mean extension at maximum load respectively) but was hard to work with while 1 per cent and 2 per cent whey gluten-free dough had the same performance.

Incorporation of potato starch significantly increased hardness from 0.30 to 13.35 N. Adhesiveness was found to be decreased with potato starch incorporation in *a chapatti*. The addition of PS reduced the gumminess, cohesiveness and chewiness of *chapatti* but with an increase in concentration increased gumminess, cohesiveness and chewiness were observed. Jafarpour *et al.* (2012) found that adding different levels of PS into common carp surimi paste decreased the hardness and cohesiveness of the resulting surimi gel; however, this showed an inverse relationship with the concentration of added PS. Hager and Aredent (2013) reported that upon the addition of potato starch adhesiveness (6.56 to 11.31), cohesiveness (0.917 to -7.308), and gumminess (141. 49 to 2.00) got decreased. Starch contributed to greater adhesiveness, cohesiveness, and gumminess of examined yoghurts, whereas the hardness of potato starch slightly lower when compared to the natural one. It is consistent with results obtained by Rawson and Marshall 1997 who stated that exopolysaccharides produced by ropy strains contributed in a greater extent to adhesiveness but the protein matrix is more responsible for hardness. On basis of textural studies, the quality and sensory attributes of maize *chapatti* JL3459 were selected for shelf life studies.

Shelf life study of developed maize *chapatti*

Moisture content

Significant variations were noticed in the moisture content of maize *chapattis* containing additives (xanthan gum 0.75 per cent, guar gum 0.75 percent, whey protein concentrate 5 per cent and potato starch 5 per cent) and control *chapatti* with and without preservatives (Table 6). Moisture content of composite *chapattis* having additives had more moisture content than the control 'chapattis' with and without preservatives. Ghodke *et al.* (2009) observed that guar gum prevented staling in *chapattis* as was monitored through various parameters. Moisture content in guar gum incorporated 'chapattis' was higher than the control 'chapattis'. Guarda *et al.* (2004) found that the bread containing hydrocolloids showed lower loss of moisture content, therefore higher water retention in the crumb compared to the control. Hydrocolloid addition reduces the dehydration rate of crumb samples during storage. Ho *et al.* (2013) also reported that higher moisture content was indicated in bread crumbs prepared by white bread (BCtrl) incorporated with banana pseudo stem flour at 100g/kg level (B10BPF), B10BPF added with hydrocolloids at 8 g/kg with xanthan gum (B10BPFXG) and B10BPF added with hydrocolloid sodium carboxymethyl cellulose (B10BPFCMC) than that of BCtr throughout the duration of storage. This was attributed to the differences in the amount of water added to the dough; the higher addition of the water to the dough resulted in a high moisture content of the crumbs. BCtr uses less water than BPFs dough to form smooth and elastic dough. BCtr had lower moisture content due to less fibre as compared to the composite bread. Processing storage period showed a decrease in moisture content during three days of storage. Variations were also significant in relation to storage days. These results are in agreement with that of Ribotta and Bail (2007), who found a reduction in crumb moisture and an increment in the crust moisture during the storage days. Baik and Chinachoti () reported that bread crumbs stored with crust showed a reduction in moisture during the 2 weeks of storage at room temperature. Czuchajowska and Pomeranz (1989) reported that the crumb moisture decreases from approximately 450 to 435 g/kg during storage. On comparing the moisture loss of composite and control *chapattis*, the moisture loss of composite *chapattis* was less than the control. Interaction between the *chapattis* prepared with additives and the storage period was found to be statistically non-significant.

pH

Significant variations were noticed in the pH value of *chapattis* prepared from (xanthan gum 0.75 per cent, guar gum 0.75 percent, whey protein concentrate 5 per cent and potato starch 5 per cent) and is tabulated in Table 6. Variations were also significant in relation to storage days. It was found that pH of *chapattis* slightly changed from basic to acidic. The acidity was found to be more in control *chapattis* than *chapatti* prepared with additives. Significant variations were also observed in pH value of chapatti with storage days. Interaction between composite *chapattis* and storage was found to be significant (CD = 0.295).

Free fatty acids

Statistically significant variations were observed in free fatty acid content in *chapatti* prepared from different additives (xanthan gum 0.75 per cent, guar gum 0.75 percent, whey protein concentrate 5 per cent and potato starch 5 per cent) and control *chapatti* with and without preservatives during storage (Table 6). Free fatty acid was maximum in *chapattis* prepared without preservatives packed in LDPE and was minimum in *chapattis* with preservatives. Statistically significant variations were also observed in *chapattis* with storage days.

Statistically significant variations were observed in the development of free fatty acids in control, *chapattis* prepared with additives and *chapatti* with preservatives under an ambient condition in low-density polyethylene. The interaction with different *chapattis* and the number

Table 6. Effect of storage condition on shelf life of 'chapattis' of different formulation prepared from maize variety (JI3459)

Formulation	Moisture (%)				pH				Free fatty acid (% oleic acid)				Peroxide value (meq O_2/kg)				Total plate count (cfu ×10^2)			
	Day				Day				Day				Day				Day			
	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
1	56.93	55.51	54.78	53.33	7.33	7.53	7.06	6.75	0	0.22	0.45	0.54	0.036	0.012	0.04	0.04	0	10	10	20
2	56.73	55.78	54.53	53.73	7.42	7.57	6.83	6.96	0	0.12	0.34	0.44	0.037	0.02	0.04	0.04	1	10	15	20
3	56.73	55.98	54.87	53.65	7.43	7.62	7.04	6.94	0	0.22	0.33	0.44	0.028	0.01	0.03	0.04	1	10	12	18
4	56.97	55.88	55.18	54.32	7.37	7.60	7.05	6.95	0	0.22	0.33	0.44	0.017	0.01	0.01	0.04	1	10	15	20
5	53.74	52.57	51.54	50.93	7.41	7.55	7.03	6.91	0	0.13	0.12	0.22	0.017	0.04	0.01	0.01	1	2	5	10
6	53.59	52.94	52.08	50.06	7.40	7.03	6.50	5.97	0.66	0.22	0.43	0.80	0.01	0.01	0.02	0.03	0	10	20	40
CD (0.05)	A=1.017 B=0.883 A×B=NS				A=0.191 B=0.156 A×B=0.383				A=0.148 B=0.121 A×B=0.295				A=0.467 B=0.381 A×B=0.933							

1 = *Chapatti* prepared with incorporation of xanthan gum 0.75 per cent
2= *Chapatti* prepared with incorporation of guar gum 0.75 per cent
3= *Chapatti* prepared with incorporation of whey protein 0.75 per cent
4 = *Chapatti* prepared with incorporation of potato starch 0.75 per cent
5 = Control *chapatti* without preservative
6= Control *chapatti* with preservative

Table 7. Consumer evaluation scores of selected maize flour formulation

Parameter	Score			
	Very good (%)	Good (%)	Fair (%)	Poor (%)
Rollability	97.2	2.5	0.3	0
Taste	96.6	3	0.4	0

of days were significant. Interaction between storage period and *chapattis* were found to be statistically significant with CD value 0.295

Peroxide value (meq O_2/kg)

Significant variations were noticed in the formation of peroxide in *chapattis* over the storage period (Table 6). The development of peroxides was mainly due to the presence of free moisture in *chapattis* and the water vapor transmission rate of packaging material. Due to less water vapor transmission rate, LDPE-packed chapattis had lower peroxide content.

Statistically significant variations were observed in *chapattis* prepared with additives and control *chapatti*. Peroxides formation was found to be highest in *chapattis* prepared from additive and minimum in *chapatti* with preservative.

Interaction between storage period and *chapatti* was found to be statistically significant with CD value 2.933.

Total plate count

Statistically significant variations were observed in the total plate count of *chapattis* stored under ambient conditions. Results are reported in Table 6. TPC was observed on each day during the storage of three days of *chapattis* the total plate count of 'chapattis' prepared from additives are more than the control *chapattis.* The total plate count was least for the *chapattis* prepared by the addition of preservatives. It was found that composite *chapattis* had more total plate count than the control *chapattis.* Ho *et al.* (2013) reported that a population of bacteria on composite bread incorporated with banana pseudo-stem flour at 100g/kg level (B10BPF) and B10BPF added with hydrocolloid xanthan gum 8g/kg (B10BPFXG) or Sodium carboxy-methylcellulose B10BPFCMC increased rapidly on the third day of storage. Higher colonies were observed in the composite bread than in white bread (BCtr). This may be attributed to the higher water content of composite bread than BCtr. The water activity of the products affects microbial growth. The high a_w value favors the growth of the microorganisms. Earlier, it has been reported that a_w value of 0.85 favoured continuous mold growth activities until oxygen concentrations fell below a certain threshold (Markova and Wadso 1998). Jay *et al.* (2005) reported that the genus *Bacillus* bacteria and several genera of molds (*Rhizopus* sp.) are usually developed on food products if there is enough moisture and a_w for growth.

Statistically significant variation was observed with regard to total plate count. Interaction between the storage period and *chapatti* showed significant variation under ambient temperature. The baking process effectively eliminated the safety risk of the microbial population present in the flour.

It has been stated that the aerobic plate count of baked food should be less than 10^5 CFU/g for safe storage and consumption (Pal, 2019). Therefore, in this study, the microbial load was much lower than the limit upto three days of storage and could be considered safe for consumption.

Consumer evaluation study

The selected maize flour containing the best level of all additives was subjected to 50 consumers for judging acceptability in terms of taste and rollability characteristics. The 97.2 per cent of consumers awarded very good, 2.5 per cent awarded good, 0.3 per cent awarded fair and 0 per cent awarded poor to the rollability character of formulated flour. It was also observed that 96.6 per cent of consumers were awarded very good, 3 per cent awarded good, 0.4 per cent awarded fair and 0 per cent awarded poor to taste the character of formulated flour. Thus, the data revealed that overall 96 per cent liked the maize formulation of *chapatti.*

It can be concluded from investigated results that Buland was rejected in the preliminary evaluation due to its poor roll-ability and negligible acceptance which was the result of its reddish colour whereas PMH1 and JL3459 with 60µ constituted fair roll-ability and sensory scores. Additives namely, xanthan gum (0.75%), guar gum (0.75%), whey protein concentrate (5%), and starch (5%) were found to be optimum in terms of preparation technology, quality, and sensory scores for maize *chapatti*. The mass consumers gave commendable scores to maize formulation in the context to rollability and texture.

Authors' contribution

Conceptualization and designing of the research work (NC,AK); Execution of field/lab experiments and data collection (NC); Analysis of data and interpretation (NC,PAS); Preparation of manuscript (NC).

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