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Effect of composite flours and additives on the texture of chapati

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Abstract

Chapaties were prepared from composite flours and the tensile properties of the chapaties were determined using an Instron Universal Testing Machine. Parameters like extensibility, peak force to rupture, modulus of deformation and energy to rupture were used to describe texture. The whole wheat flour was replaced with flours from rice, corn, barley, millets and black gram. Effect of additives like skim milk powder, wet gluten, liquid shortening, carboxymethylcellulose, glycerol monosterate, sodium caseinate and diastase on chapati texture was also evaluated. Upon storage up to 24 h, the extensibility and energy to rupture decreased whereas modulus of deformation and peak load to rupture increased. It was observed that chapaties made from some composite flours showed higher extensibility even after 24 h of storage, especially barley. Some of the additives like wet gluten and sodium caseinate also significantly improved the texture of chapati.

1. Introduction

Chapaties are unleavened flat breads made from whole wheat flour (atta) and have served as the staple food of the Indian subcontinent and parts of the Middle East for centuries. In India, the traditional method of processing wheat is carried out by grinding it into flour with chakky which consists of heavy granite stones of equal diameter (one rotating and the other stationary). The ground whole wheat flour (atta) spilling out from the gap between the stones is collected and sieved to remove the coarsest particles of bran giving a flour of over 95% extraction rate. This flour is an excellent source of nutrition and dietary fiber. The higher starch damage caused by the stone mill results in increased water absorption yielding softer and more pliable chapaties. During storage the chapaties become stale and difficult to chew. A method is required to objectively describe the texture of chapaties.

Where wheat flour is not plentiful or constitutes an expensive imported material, it becomes necessary to consider other cereal flours or starchy materials that may be used to make chapaties. Rice is consumed mostly in the form of whole grain after dehusking and polishing. During the milling process brokens are also produced which fetch a lower price in the market. These brokens can be ground into flour and may be used to replace part of the wheat flour in chapaties. Flours from other cereals or legumes could also be used. Such composite flours are used for improving protein content and nutritive value of wheat flour products. Chapaties have been enriched with soy flour to improve nutritional quality (Lindell & Walker, 1984). Barley flour and germinated wheat flour have been incorporated in wheat flour to yield acceptable chapaties (Sood, Dhaliwal, Kalia, & Sharma, 1992; Anjum, Ali, & Chaudhry, 1991; Leelavathi & Haridas Rao, 1988). Davinder Kaur and Hira (1988) studied the organoleptic acceptability of chapaties made from combination of durum and aestivum wheat supplemented at different levels with Bengal gram flour and soy protein concentrate. Rajagopal, Mudambi, and Pasi (1983) studied addition of soy flour or rice bean flour to wheat flour to improve the nutritional quality of chapati. Sekhon, Gill, Saxena, and Sadhna (1980) reported that triticale could be blended with wheat at a level of 50% to make chapaties. Arya, Vanaja, and Parihar (1978) reported that wheat varieties having higher levels of lipids gave chapaties with a softer texture. Jain, Sarrar, Mehmood, and Ali (2000) reported that chapaties made from fortified wheat flour with defatted soy bean flour were acceptable but those made from rape seed and sunflower flours were unacceptable. Haridas Rao, Leelavathi, and Shurpalekar (1986) reported that height of puffed chapati and pliability can

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serve as simple indices of chapati quality. The objectives of the present investigation were to objectively study the tensile properties of chapati, how the texture was affected by composite flours and additives and changes occurring in texture during storage.

2. Materials and methods

Wheat variety PBW-343 was procured from Punjab Agriculture University, Ludhiana from 2000 harvest. The wheat was cleaned and conditioned to 14% moisture content and then milled into whole wheat flour in a stone mill (chakky) at a local miller. The mill consisted of horizontally aligned granite stones each having a diameter of 75 cm. The bottom stone was stationary while a 20 HP motor was running the upper stone at 300 rpm. The whole wheat flour spilling out from the gap between the stones was collected. It was sifted through sieves of different mesh (44, 52, 72 and 100) size and particle size distribution was determined (Gujral, Singh, & Singh, 2001). Brokens from rice cultivar IR-8 (Singh, Singh, Kaur, & Bakshi, 2000) remaining after the polishing process were collected and ground in a hammer mill to pass through 60 mesh sieve. Decorticated black gram were procured from the local market and ground to pass through 60 mesh sieve. Corn cultivar ‘Partap’ was procured from Punjab Agriculture University, Ludhiana. The corn was conditioned, degermed and polished (Gujral & Singh, 2001) and then ground to pass through 60 mesh sieve. Barley flour was obtained by milling ‘PL-426’ variety in a stone mill and flour was sifted through 60 mesh sieve. Millet flour was obtained from the local market. Wet gluten was obtained by washing wheat flour (PBW-343) dough under running water to remove the starch (Singh, Singh, & Kaur, 1998). Liquid shortening (Sundrop, Premier Soy Oil Ltd., Jaipur) was procured from local market. Skim milk powder was procured from Milk Plant Verka, Amritsar. Glycerol monosterate, diastase and carboxymethylcellulose were obtained from CDH Chemicals, New Delhi, and sodium caseinate from Wilson Laboratories, Mumbai.

2.1. Chapati making

Whole wheat flour (atta), 150 g was mixed with optimum water (Gujral & Singh, 1999; Singh et al., 1998) for three minutes in a laboratory mixer (National Manufacturing Company, Lincoln, NE). The dough was rested for half an hour. Dough (50 g) was rounded and then placed on the rolling board and was sheeted to a diameter of 155 mm and a thickness of 2 mm using a rolling pin. The dough was rolled in one direction, inverted and then rolled in a perpendicular direction. The raw chapati was immediately placed on a hot plate (tawa) and heated for 15 s at 220 °C on one side and 10 s at 220 °C on the other side. It was again turned and baked for 35 s at 290 °C. The chapati was allowed to cool for 10 min at 25 °C and then packed in polyethylene pouches and placed in a air tight container at 25 °C. Rectangular strips of 90 mm × 18 mm were cut from the center of the chapati using a metal template. This strip of chapati was then tested for extensibility on the Instron Universal Testing Machine. The chapati strip was seated between two clamps. One clamp was attached to the moving arm of the Instron and the other was attached to the platform (Fig. 1). Both the clamps were properly aligned and set at 50 mm apart. A load cell of 100 N was used at a cross head speed of 50 mm/min to pull the chapati strip apart until it ruptured. The extension displacement curve was obtained (Fig. 2) and from this various parameters like the modulus of deformation (tensile modulus), load to rupture (kN), energy to rupture (J) and extensibility (mm) were calculated (Sharma, Mulvaney, & Rizvi, 2000).

$$\text{Tensile modulus (MPa)} = \frac{\text{Tensile stress}}{\text{Tensile strain}} = \frac{F/A}{\Delta L/L}$$

where F is the load (peak force) to rupture, A is cross-section area (m^2), L is initial length (m) of chapati and ΔL is change in length (extensibility).

The chapaties were stored for 24 h in a air tight container at room temperature and later subjected to the extensibility test. The entire experiment was repeated thrice and a total of eighteen strips were tested for each

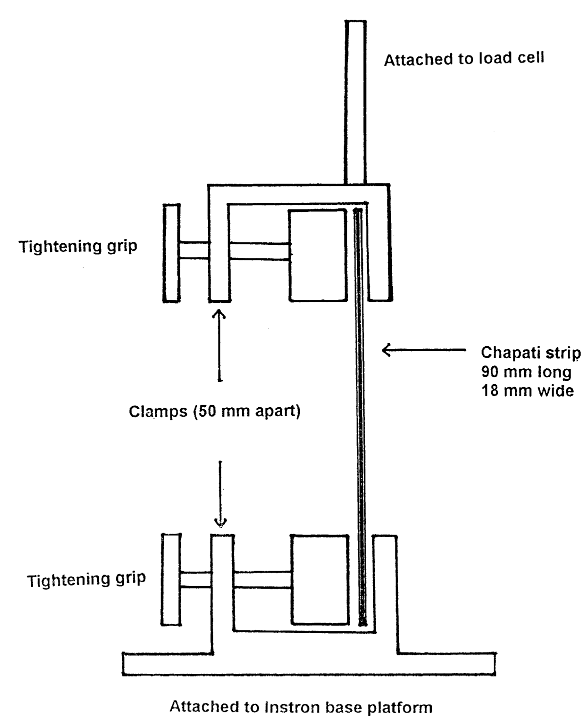

Fig. 1. Attachment for measuring chapati extensibility.

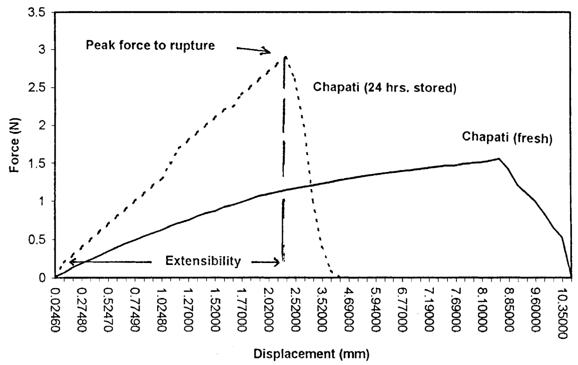

Fig. 2. Force deformation curve for fresh and stale chapati (24 h stored).

sample and average values were reported (Bawa & Singh, 1998; Steele & Torrie, 1960).

3. Results and discussion

The particle size distribution of the whole wheat flour was such that 11.3%, 1.9%, 44% and 28.4% was retained by 44, 52, 72 and 100 mesh sieves and 14.4% passed through 100 mesh sieve. The flour had an extraction rate, protein content and ash content of 94%, 9.5% and 1.87%, respectively. The force needed to extend the chapati strip increased during tensile deformation (extension) and reached a maximum before the strip ruptured and then decreased after rupture (Fig. 2). Fresh chapati was soft and extensible as indicated by low force values required to deform, low modulus of deformation and longer distances of extension before rupture (Table 1). The chapati stored for 24 h was hard and brittle as indicated by the high force values, high modulus of deformation and short distances of extension before rupture (Table 2). Since the chapati was sealed in airtight container the decrease in extensibility could not be attributed to the loss in moisture but to recrystallization and retrogradation of starch in the chapati, a very common phenomenon which occurs in bread (Guy, Hodge, & Robb, 1983). Control chapati showed an extensibility of 8.117 mm after 30 min of baking but this decreased to 2.213 mm after 24 h of storage. The maximum force required to rupture the chapati increased from 0.0019 to 0.003 kN after 24 h of storage. The modulus of deformation also increased from 0.260 to 1.506 MPa. The energy required to rupture the chapati strip decreased from 0.0164 to 0.005 J. The whole wheat flour was passed through four different sieves having mesh size of 44, 52, 72 and 100 so as to obtain flour of varying particle size. It is well known that as particle size decreases the protein content of flour increases. As the flour fineness increased the extensibility of chapati increased and chapaties remained more extensible even after 24 h of storage. Peak force to rupture and energy to rupture also increased with increasing flour fineness.

3.1. Composite flours

Whole wheat flour was replaced with rice flour at levels of 10–50%. Rice flour increased the extensibility of the chapati but at higher levels lead to a decrease in the extensibility (Table 1). This decrease can be attributed to the absence of gluten proteins in the rice flour. Increasing levels of rice flour lead to a decrease in both the peak force to rupture, energy to rupture and modulus of deformation of fresh chapati but after 24 h of storage the modulus of deformation significantly increased with increasing levels of rice flour.

Bengal gram flour increased the extensibility but at higher levels the extensibility was lower than that of the control chapati. Increasing levels of Bengal gram flour lowered the peak force to rupture and increased modulus of deformation. Addition of corn flour increased the extensibility but this decreased with increasing level of corn flour. The peak force to rupture increased with corn flour addition but at higher levels it led to a constant decrease. This might be attributed to the absence of gluten protein in corn flour. Chapaties containing corn flour showed lower modulus of deformation as compared to the control sample. The chapati containing corn flour remained more extensible and soft even after 24 h of storage.

Addition of barley flour to wheat flour increased the extensibility of chapati to 12.91 mm at 20% level of addition but at higher levels it started to decrease. After 24 h of storage the extensibility remained significantly higher than the control sample. Barley flour contains high levels of β-glucan which may be involved in preventing the retrogradation of starch and thus keeping the chapati more extensible (Bhatty, 1995). Chapati containing barley flour showed higher peak force to rupture and energy to rupture, which remained higher after 24 h of storage.

Incorporation of millet flour in wheat flour at 10% level significantly increased the extensibility of chapati to 11.29 mm but at higher levels of addition the extensibility decreased. The decrease may be attributed to the dilution of gluten proteins. Chapaties containing millet flour remained more extensible than the control sample after 24 h of storage. Millet flour caused an increase in the peak force to rupture, modulus of deformation and energy to rupture.

3.2. Effect of additives

Increasing levels of wet gluten significantly increased the extensibility and the chapati remained extensible even after 24 h of storage. The antifirming effect of increased gluten has been reported by Wilhoft (1973), Kim

Table 1
Texture of fresh chapati (30 min)

Sample	Extensibility (mm)	Peak load to rupture (kN)	Modulus of deformation (MPa)	Energy to rupture (J)	Water absorption (%)
Control	8.117	0.0019	0.260	0.0164	57
Rice flour (%)					
5	10.91^{a}	0.0025^{a}	0.254^{a}	0.0231^{a}	57.6
10	9.89^{b}	0.00234^{a}	0.262^{a}	0.017^{b}	58
15	9.62^{b}	0.0017^{a}	0.196^{b}	0.0162^{b}	59.3
20	8.61^{c}	0.00159^{b}	0.193^{b}	0.0171^{b}	61
30	7.85^{d}	0.00151^{b}	0.212^{b}	0.0165^{b}	62
40	7.51^{d}	0.00148^{b}	0.218^{b}	0.0143^{b}	62.6
50	7.24^{d}	0.0014^{b}	0.214^{b}	0.0137^{b}	63.3
Black gram flour (%)					
5	11.77^{a}	0.0033^{a}	0.311^{a}	0.214^{a}	60
10	9.08^{b}	0.0028^{b}	0.342^{a}	0.193^{b}	62
15	6.91^{c}	0.0027^{b}	0.434^{b}	0.167^{c}	57
20	6.43^{c}	0.0024^{b}	0.414^{b}	0.147^{c}	56.6
30	6.53^{c}	0.0023^{b}	0.391^{b}	0.092^{d}	53.3
Corn flour (%)					
10	11.007^{a}	0.0025^{a}	0.252^{a}	0.0228^{a}	63.3
20	10.29^{b}	0.0023^{a}	0.248^{a}	0.0166^{b}	76.6
30	9.02^{c}	0.0019^{b}	0.234^{a}	0.0124^{b}	83.3
40	8.07^{d}	0.0017^{b}	0.234^{a}	0.01003^{c}	90
50	7.75^{e}	0.0016^{b}	0.229^{a}	0.0098^{c}	93.3
Barley (%)					
10	9.96^{a}	0.00246^{a}	0.274^{a}	0.0251^{a}	66.7
20	12.91^{b}	0.0029^{b}	0.249^{a}	0.0337^{b}	71.3
30	9.42^{a}	0.0024^{a}	0.283^{a}	0.024^{a}	72.3
40	7.71^{c}	0.0023^{a}	0.331^{b}	0.012^{c}	73.3
Millets (%)					
10	11.29^{a}	0.0036^{a}	0.354^{a}	0.0425^{a}	63.3
20	5.14^{b}	0.0026^{b}	0.240^{b}	0.0159^{b}	64.7
30	5.11^{b}	0.0024^{b}	0.521^{c}	0.0148^{b}	66.6
Particle size (mesh)					
44	8.117^{a}	0.0019^{a}	0.260^{a}	0.0164^{a}	56.6
52	11.99^{b}	0.0026^{b}	0.240^{a}	0.0381^{b}	58
72	12.06^{b}	0.0033^{c}	0.304^{b}	0.0433^{c}	59
100	15^{c}	0.00195^{a}	0.144^{c}	0.0398^{b}	60
Wet Gluten (g)					
15	9.08^{a}	0.0024^{a}	0.293^{a}	0.0285^{a}	53.3
30	13.67^{b}	0.0022^{a}	0.178^{b}	0.052^{b}	54.6
45	18.6^{c}	0.0021^{a}	0.125^{c}	0.195^{c}	56.6
Liquid shortening (%)					
2.5	13.46^{a}	0.003^{a}	0.247^{a}	0.0291^{a}	52
5	10.86^{b}	0.0028^{a}	0.286^{a}	0.0257^{a}	51.3
7.5	8.76^{c}	0.0024^{a}	0.304^{a}	0.0150^{b}	50
10	8.73^{c}	0.002^{b}	0.254^{a}	0.0133^{b}	46.6
Skim milk powder (%)					
2.5	5.16^{a}	0.0011^{a}	0.236^{a}	0.0216^{a}	53.3
5	6.84^{b}	0.0026^{b}	0.422^{b}	0.0196^{a}	52.6
7.5	7.57^{c}	0.0027^{b}	0.396^{b}	0.0153^{b}	52
10	9.208^{d}	0.0034^{c}	0.410^{b}	0.0147^{b}	51.3
Carboxymethylcellulose (%)					
0.5	10.22^{a}	0.0035^{a}	0.380^{a}	0.0204^{a}	59
1	12.07^{b}	0.0028^{b}	0.257^{b}	0.0211^{b}	63.3
1.5	12.12^{b}	0.0024^{b}	0.220^{b}	0.0225^{c}	64.8

Table 1 (*continued*)

Sample	Extensibility (mm)	Peak load to rupture (kN)	Modulus of deformation (MPa)	Energy to rupture (J)	Water absorption (%)
Glycerol monosterate (%)					
0.25	8.69[a]	0.0027[a]	0.345[a]	0.022[a]	58
0.5	13.8[b]	0.0029[a]	0.233[b]	0.0314[b]	58.6
1	14.3[b]	0.0031[a]	0.240[b]	0.0341[b]	59.3
Sodium caseinate (%)					
0.5	12.17[a]	0.0028[a]	0.255[a]	0.0298[a]	62.1
1.5	12.19[a]	0.0027[a]	0.246[a]	0.0283[a]	68.7
2.5	13.18[b]	0.0024[a]	0.202[a]	0.0259[a]	72.3
Diastase (%)					
0.15	7.52[a]	0.0022[a]	0.325[a]	0.0183[a]	57.2
0.375	7.80[a]	0.0023[a]	0.327[a]	0.0174[a]	57.6
0.75	8.23[b]	0.0025[a]	0.337[a]	0.0167[a]	58.6

Superscripts with the same letters are not significantly different ($P > 0.05$).

Table 2
Texture of chapati (stored for 24 h)

Sample	Extensibility (mm)	Peak load to rupture (kN)	Modulus of deformation (MPa)	Energy to rupture (J)
Control	2.213	0.0030	1.506	0.005
Rice flour (%)				
5	3.69[a]	0.00367[a]	1.084[a]	0.0089[a]
10	2.96[b]	0.0041[c]	1.539[b]	0.0087[a]
15	2.8[b]	0.0035[a]	1.388[c]	0.006[b]
20	2.70[b]	0.0037[a]	1.522[b]	0.0043[c]
30	2.235[c]	0.0029[b]	1.444[d]	0.0040[c]
40	2.21[c]	0.0044[c]	2.210[e]	0.0039[c]
50	2.2[c]	0.0046[c]	2.32[f]	0.0038[c]
Black gram flour (%)				
5	2.95[a]	0.0027[a]	1.017[a]	0.0039[a]
10	3.01[a]	0.0028[a]	1.034[a]	0.0041[b]
15	3.18[b]	0.0029[a]	1.013[a]	0.0048[c]
20	3.25[b]	0.0038[b]	1.299[b]	0.0072[d]
30	3.27[b]	0.0045[c]	1.520[c]	0.0081[e]
Corn flour (%)				
10	3.77[a]	0.0038[a]	1.119[a]	0.0082[a]
20	3.006[b]	0.0026[b]	0.961[c]	0.0059[b]
30	2.51[c]	0.0024[b]	1.062[b]	0.0048[c]
40	2.31[c]	0.0023[b]	1.106[a]	0.0036[d]
50	2.22[c]	0.0021[b]	1.051[b]	0.0029[e]
Barley (%)				
10	5.195[a]	0.0050[a]	1.069[a]	0.0213[a]
20	5.37[a]	0.0030[b]	0.620[b]	0.0237[b]
30	5.31[a]	0.0033[b]	0.690[c]	0.0234[b]
40	5.28[a]	0.0036[b]	0.757[d]	0.0226[b]
Millets (%)				
10	3.91[a]	0.0043[a]	1.22[a]	0.0133[a]
20	3.33[a]	0.0035[b]	1.16[a]	0.0084[b]
30	2.85[b]	0.0023[c]	0.896[b]	0.0046[c]
Particle size (mesh)				
44	2.213[a]	0.0030[a]	1.506[a]	0.009[a]
52	3.562[b]	0.0048[b]	1.497[a]	0.0136[b]
72	3.47[b]	0.0050[b]	1.601[b]	0.0122[c]
100	3.40[b]	0.0051[b]	1.667[b]	0.0121[c]

(*continued on next page*)

Table 2 (*continued*)

Sample	Extensibility (mm)	Peak load to rupture (kN)	Modulus of deformation (MPa)	Energy to rupture (J)
Wet Gluten (g)				
15	5.14[a]	0.0042[a]	0.907[a]	0.132[a]
30	5.39[a]	0.0034[b]	0.701[b]	0.0139[a]
45	5.82[b]	0.0024[c]	0.458[c]	0.148[a]
Liquid shortening (%)				
2.5	2.35[a]	0.0038[a]	1.796[a]	0.0041[a]
5	2.423[a]	0.0037[a]	1.276[b]	0.0042[a]
7.5	2.453[a]	0.0035[a]	1.585[c]	0.0043[a]
10	2.676[a]	0.0034[a]	1.411[d]	0.0047[a]
Skim milk powder (%)				
2.5	3.220[a]	0.0038[a]	1.311[a]	0.0069[a]
5	3.385[a]	0.0046[b]	1.509[b]	0.008[b]
7.5	3.560[a]	0.0051[c]	1.591[c]	0.0105[c]
10	3.750[a]	0.0052[c]	1.540[c]	0.0138[c]
Carboxymethylcellulose (%)				
0.5	2.375[a]	0.0029[a]	1.356[a]	0.0013[a]
1	4.24[b]	0.0038[b]	0.995[b]	0.0034[b]
1.5	4.31[b]	0.0027[a]	0.696[c]	0.0049[c]
Glycerol monosterate (%)				
0.25	4.050[a]	0.0051[a]	1.399[a]	0.0170[a]
0.5	3.480[b]	0.004[b]	1.272[b]	0.0142[a]
1	2.915[c]	0.0036[b]	1.372[a]	0.0114[a]
Sodium caseinate (%)				
0.5	4.94[a]	0.0048[a]	1.079[a]	0.0183[a]
1.5	4.15[b]	0.0041[b]	1.097[a]	0.0114[b]
2.5	4.14[b]	0.0035[b]	1.064[a]	0.0108[b]
Diastase (%)				
0.15	3.875[a]	0.0030[a]	0.860[a]	0.0099[a]
0.375	3.52[a]	0.0031[a]	0.978[b]	0.0074[b]
0.75	2.45[b]	0.0035[a]	1.587[c]	0.0058[c]

Superscripts with the same letters are not significantly different ($P > 0.05$).

and D'Appolonia (1977). Gluten lowered the modulus of deformation but increased the peak force to rupture. Liquid shortening was added to chapati at levels of 2.5–10% and this significantly increased the extensibility but the extensibility decreased with increasing levels of liquid shortening. After 24 h of storage the chapati containing liquid shortening remained more extensible than the control chapati. This can be attributed to the interference of the triglycerides with starch retrogradation and preventing staling of chapati. Liquid shortening increased the modulus of deformation, peak force to rupture and energy to rupture. Addition of skim milk powder decreased the extensibility but at higher levels the extensibility increased. At higher levels the chapati containing skim milk powder showed higher extensibility than the control samples even after 24 h of storage. Addition of skim milk powder increased the energy to rupture but this was lowered at higher levels of addition.

Addition of carboxymethylcellulose significantly increased the extensibility of chapati and the chapati remained more extensible than the control sample even after 24 h of storage. Carboxymethylcellulose lowered the modulus of deformation but increased the peak force to rupture. Changes brought about by carboxymethylcellulose might be attributed to its ability to absorb large amounts of water. Rate of firming has an inverse relationship to crumb moisture content (Rogers, Zeleznak, Lai, & Hoseney, 1988). Glycerol monosterate significantly increased the extensibility of the chapati and chapati remained significantly extensible after 24 h of storage. This may be attributed to the emulsifying and antistailing properties of glycerol monosterate. Peak force to rupture and energy to rupture significantly increased with the addition of glycerol monosterate.

Increasing levels of sodium caseinate significantly increased the extensibility of chapati as compared to control chapati. This increase might be attributed to the emulsifying and water binding properties of sodium caseinate. After 24 h of storage the chapaties containing sodium caseinate remained significantly more extensible than the control sample. Sodium caseinate increased the peak force to rupture and energy to rupture both in the fresh and 24 h stored chapati.

Diastase brings about hydrolysis of starch. The purpose of addition was to study if starch depolymerization had any effect on chapati texture. Diastase addition did not significantly affect the extensibility of fresh chapati however it showed higher values of peak force to rupture, energy to rupture and modulus of deformation. Chapati containing diastase remained more extensible than the control chapati after 24 h of storage. This might be attributed to the lower reassociation and retrogradation of the starch because of its depolymerization by diastase.

4. Conclusion

The study revealed that chapaties could be made by using composite flours in which the whole wheat flour was replaced with flours from rice, corn, barley, millets or black gram flour either to improve taste, texture, economize the product or improve nutritional quality. Additives like liquid shortening, CMC, GMS and sodium caseinate significantly increased the extensibility of chapati and keep the chapati more extensible after 24 h of storage. The particle size and gluten content of the whole wheat flour had significant effect on extensibility of chapati. Enzymes like diastase can be added to depolymerize the starch and thus delay staling. The attachment designed to measure extensibility is easily used on the Instron Universal Testing Machine and the results are reproducible.

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