Changes in the Quality Characteristics of Chapati During Storage[1]

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ABSTRACT

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The tearing resistance tester and Warner Bratzler shear press have been adapted successfully to evaluate, objectively, the quality changes in chapati during storage. Tearing strength, indicative of development of brittleness, decreased markedly from 72.5 to 31.0 g and only slightly during three days' storage when chapati was packed in polyethylene pouches and in waxed paper, respectively. Warner Bratzler shear value served as an index of texture and decreased by 21 and 46% for chapaties packed in waxed paper and polyethylene pouches, respectively. A simple pliability tester was devised to measure chapati pliability. When chapaties were packed in waxed paper, pliability decreased from 2.3 to 1.2 cm, but increased from 2.1 to 4.4 cm when packed in polyethylene pouches. Although no significant difference was observed in salt-soluble proteins and ether extractives during storage, starch was found to be affected significantly. This was indicated by decreases in water retention capacity, falling number, enzyme-susceptible starch, and soluble starch. Furthermore, both amylose and amylopectin were found to decrease, possibly contributing thereby to staling of chapati. Although heat treatment of chapati packed in a polyethylene pouch delayed mold attack from three to 90 days, the chapati had a somewhat cooked flavor and was brittle, as indicated by the marked decrease in shear value. Addition of salt (1.25%), glycerol monostearate (0.5%), sorbic acid (0.2%), and fat (4%) minimized the development of brittleness to some extent.

Chapati, an unleavened baked flat bread, is the staple diet of a majority of the people living in the Indian subcontinent. Chapati is generally prepared and consumed fresh in households, as well as in restaurants. There is considerable potential for the large-scale manufacture and marketing of chapati, in view of the steadily increasing demand of the urban population for ready-to-eat and convenient food products. Large-scale production of chapati calls for mechanization and marketing in suitable unit packs. When it reaches the consumer, the packed chapati should retain all the characteristics of fresh chapati.

Narindar Nath et al (1957) observed a slight increase in the fat acidity and reducing sugar content of chapati during storage. Kameshwara Rao et al (1964) reported that chapati containing 0.3% salt and 5% sorbic acid and packed in a polyethylene pouch or in an aluminum foil/polyethylene laminate, kept well for 180 days without mold growth. Sorbic acid level could be reduced either by incorporating citric acid (0.4%), sugar (3%), and salt (2.5%) or by heating the packaged chapati in an oven for 2 hr at 90°C (Arya et al 1977). As very little information is available on the qualitative changes in chapati during storage, this study was undertaken to assess the changes in the physical, chemical, and organoleptic qualities of chapati during storage, as well as the feasibility of improving its keeping quality.

MATERIALS AND METHODS

Whole Wheat *Atta*

A commercial, medium-hard wheat variety was procured locally. It was cleaned and ground in a disk mill to obtain whole wheat flour (*atta*).

Packaging Materials

Polyethylene pouches of 150 gauge (LDPE), 20 × 15 cm, and waxed (both sides) paper having wax grammage of 20 g, obtained from a local market, were used for storing chapaties.

Preparation of Chapati

A dough of optimum consistency was made by mixing 200 g of flour in a Hobart mixer (model N-50) for 3 min with a quantity of water equivalent to chapati water absorption determined by farinograph as described by Shurpalekar and Prabhavati (1976). About 45 g of the dough was sheeted to a thickness of 2.0 mm using a specially designed platform (Shurpalekar and Prabhavati 1976) and cut into a circle, 15 cm in diameter, using a steel cutter. The chapati sheet was then baked on one side for 45 sec, and on the other side for 105 sec, on a hot plate maintained at 205°C. Finally, it was puffed in a gas *tandoor* oven maintained at 345°C.

Chapati Storage

Four chapaties weighing 27–28 g each were packed in a polyethylene pouch and heat sealed. Four more chapaties were wrapped in waxed paper, and the ends were heat sealed. Another four chapaties were stored in a box made of 1-mm-thick plastic—a common practice in households. All samples were stored at atmospheric conditions of temperature (25–27°C) and humidity (60–65%).

Evaluation of Chapati

Stored chapaties were evaluated for pliability, texture, aroma, and taste by a panel of six judges at intervals of 4, 8, 12, 24, 48, and 72 hr. The overall quality of chapati was determined on the basis of the above characteristics, giving due weight to taste, texture, and aroma; they were graded as excellent, good, fair, poor, and very poor (Shurpalekar and Prabhavati 1976).

Pliability

In addition to subjective sensory evaluation, the pliability of chapati was determined with the help of a newly devised pliability tester (Fig. 1). The instrument consists of an iron stand with a vertically movable clamp for holding a strip of chapati. At the end of the base of the stand, a horizontally movable graduated scale is fixed vertically. Preliminary studies indicated that a chapati strip of 7 × 2 cm was optimum. This was indicated by the maximum difference in the pliability value between chapaties made from different wheat varieties. Hence, strips of experimental chapaties of this size and weight were fixed to the clamps, so that a 2-cm length was held between the two plates of the clamp. The remaining 5-cm length of chapati was free to bend under its own weight. The extent of bending depends upon the pliability, which is read (in cm) on the attached scale.

Tearing Resistance

The tearing resistance tester (Elmendor paper tearing tester, UK), normally used for evaluation of paper and paper boards, was adapted for objective evaluation of tearing strength, which has been reported to be one of the quality parameters of chapati (Austin and Ram 1971). The tearing strength of chapati was determined according to the standard procedure normally adapted for paper. The chapati was cut into pieces 100 × 62 mm using the standard specimen cutter provided with the instrument. Two 18-mm slits were made in the chapati 25 mm from each end. The chapati was then fixed in position, and the tearing resistance

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measured in grams. Values for three chapaties were recorded and the average calculated.

Shear Value

Shear values were measured with the Warner Bratzler (WB) shear press. The chapaties were folded into four layers and placed in the center of the single conical blade provided with the instrument. The maximum shear force needed to shear the chapati was recorded.

Statistical Analysis

Variables were analyzed by Duncan's new multiple range test (Duncan 1955).

Freeze-Drying of Chapati

The stored chapaties used for chemical analysis were cut into small strips (1 × 1 cm) and dried at a vacuum of 10^{-3} torr (0.133 × 10^{-3}kPa) in a freeze-drier (Atlas, Denmark). Drying continued until no further loss in weight of the sample was noticed. The sample was saved and used for analysis.

Chemical Analysis

Moisture content (two-stage method), ether extractives, damaged starch, diastatic activity, and falling number were determined according to standard AACC methods (1976). Reducing sugars were determined according to the method described by Austin and Ram (1971).

Water retention capacity was determined by incubating a 2-g sample in 20 ml of water overnight, and determining weight gained by the chapati powder after centrifuging the suspension for 15 min at 47 g and decanting the supernatant. The increase in the weight of the sample, expressed as percentage of initial weight, was called the "water retention capacity."

Total amylose, soluble starch, and soluble amylose contents in chapati were determined by the method described by Sowbhagya and Bhattacharya (1971) for rice. Amylose was extracted by incubating a 2-g sample with 20 ml of water overnight and centrifuging the suspension. The supernatant was used for estimation of soluble amylose content.

Heat Treatment of Chapati

Chapaties packed in polyethylene pouches were heated in an oven maintained at 90° C for periods ranging from 0 to 90 min. The samples were stored at ambient atmospheric conditions and evaluated for various quality characteristics at different intervals. Each study described above was carried out in quadruplicate.

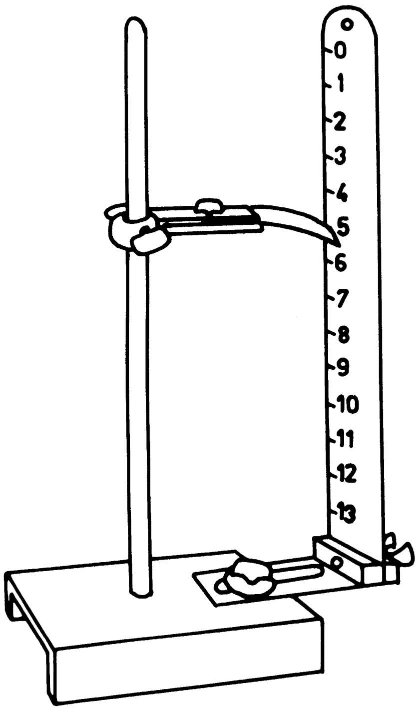

Fig. 1. Pliability tester.

RESULTS AND DISCUSSION

Moisture in Stored Chapati

Moisture in stored chapati (Fig. 2) packed differently showed that the chapati kept unwrapped in an open container under atmospheric conditions (27° C and 66% rh) dried very rapidly. The moisture content decreased from 30.8 to 14.8% within 4 hr and reached an equilibrium value of 5.8% after 24-hr storage.

Negligible moisture loss (0.2%) was observed in chapati stored either in a polyethylene pouch or plastic container for three days, whereas those wrapped in waxed paper showed a gradual decrease from 30.5 to 23.6% moisture. The higher moisture loss in chapati stored in waxed paper was probably due to higher moisture permeability of waxed paper.

Changes in Physical Characteristics

The changes in the physical characteristics of chapati during storage in different packaging materials are given in Table I.

Pliability

The pliability, as determined on the pliability tester, decreased rapidly in unwrapped chapaties (from 2.3 to 0.5 cm within a 4-hr storage period). The chapati became very tough at the end of 8 hr of

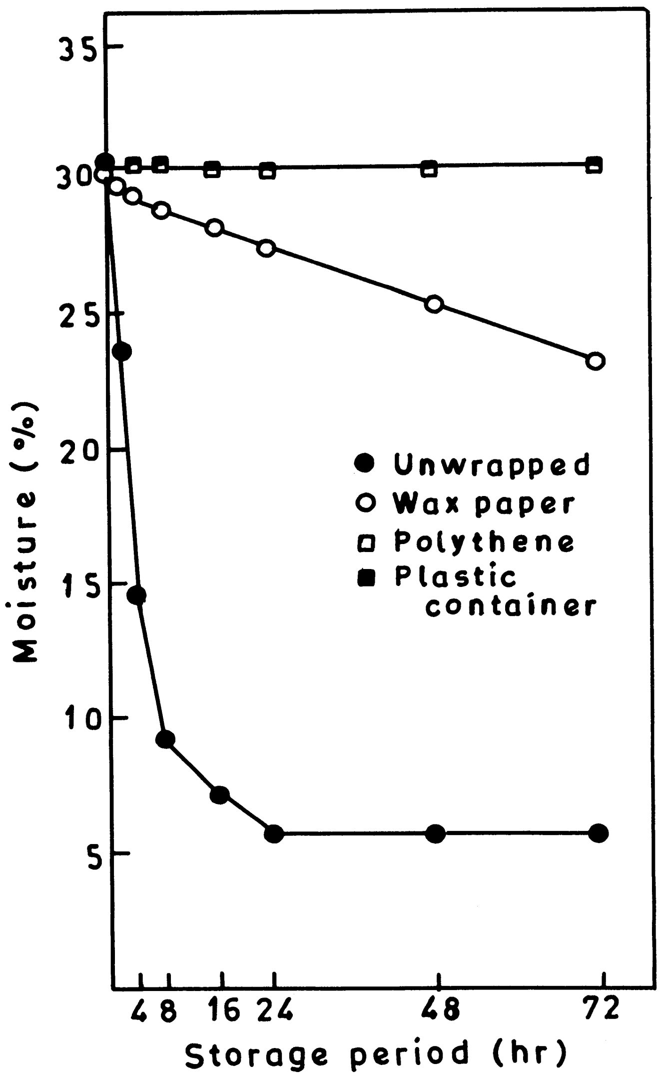

Fig. 2. Moisture loss of chapaties stored in different packaging materials.

storage, and its pliability value was zero. However, for the chapati wrapped in waxed paper, loss of pliability was gradual and ran parallel to the loss of moisture. The pliability decreased from 2.3 to 1.2 cm during three days of storage. A slight increase in the pliability observed at the end of 2 hr of storage was possibly due to equilibration of moisture within the chapati. A highly significant correlation was found between moisture loss in stored chapati and pliability value ($r = \pm0.96$). The decrease in pliability of chapati stored in waxed paper was confirmed by subjective evaluation by a panel of judges.

Interestingly enough, for chapati packed in a polyethylene pouch, a significant increase in pliability (from 2.1 to 4.3 cm) was observed after 4 hr of storage; further storage did not change the pliability value. This increase in pliability could be attributed to equilibration of moisture from the central doughy portion to the relatively dry surface. This was confirmed by the increase in the moisture content of the top, puffed layer of chapati, from 18% in a freshly baked chapati to 24% in a chapati stored for 4 hr. This phenomenon of migration of moisture is similar to the crust staling normally observed in bread. The sensory panel could not find any difference in the pliability of chapati after 4 hr of storage.

Tearing Resistance

Austin and Ram (1971) reported that good quality chapaties should give minimum resistance to tearing. Different trials carried out using chapaties made from the same wheat as well as different wheats indicated that the tearing resistance tester could be used to measure, objectively, the tearing strength of chapati. Chapaties which were quite chewy and made from flour with a high protein content had a high tearing resistance value and vice versa (Haridas Rao 1982). The tearing resistance of stored chapati increased considerably (from 72.5 to 120.0 g) when the chapati was kept in the open for only 4 hr. Chapaties stored in waxed paper showed a gradual and slight increase in tearing resistance from 72.5 to 74.5 g) during two days of storage. Thereafter, decrease in the tearing resistance, to 70.6 g at the end of three days of storage, was probably a result of the development of brittleness. The increase in the tearing resistance value observed in unwrapped chapati as well as those stored in waxed paper was probably due to the loss of moisture. In the case of chapati stored in a polyethylene pouch, the tearing resistance decreased considerably after 1 day of storage. The value was found to be as low as 31 g at the end of three days, compared to 68.0 g observed at the end of two days, probably caused by staling of chapati.

The decrease in tearing resistance on storage was also confirmed by the panel of judges who found that chapaties stored in a polyethylene pouch were easier to tear than freshly baked ones. The change in tearing resistance could not be attributed to moisture, as there was no change in moisture content. Hence, it is likely that, as with bread (Maga 1975), chemical changes unrelated to moisture content might have taken place during storage.

WB Shear Value

It has been reported (Haridas Rao 1982) that a highly significant correlation exists between WB shear value of chapati and sensory texture ($r = +0.67$, $P < 0.001$) as well as overall quality ($r = -0.59$, $P < 0.001$). WB shear value increased considerably (from 8.9 to 12.1 lb) when chapati was kept in the open for 4 hr, indicating the tough nature of stored chapati. A significant decrease in the WB shear value was observed when chapati was stored in either waxed paper or in a polyethylene pouch; the decrease was greater (from 8.9 to 4.8 lb) in chapati stored in polyethylene.

Organoleptic Quality

The organoleptic quality of chapati stored in different packaging materials showed that chapati kept unwrapped became hard and brittle, as well as gritty and dry, after 4 hr of storage. The chapati stored in waxed paper had a bland taste and flavor at the end of 72

TABLE I
Changes in the Physical Characteristics of Chapaties Stored in Different Packaging Materials

	Unwrapped				Waxed Paper				Polyethylene Pouch			
Storage Period (hr)	Moisture (%)	Pliability (cm)	Tearing Resistance (g)	WB[a] Shear Value (lb)	Moisture (%)	Pliability (cm)	Tearing Resistance (g)	WB Shear Value (lb)	Moisture (%)	Pliability (cm)	Tearing Resistance (g)	WB Shear Value (lb)
0	30.8	2.3 a[b]	72.5 a	8.9 a	30.5	2.3 a	72.5 a	8.9 a	30.7	2.1 a	72.5 a	8.9 a
2	23.8	1.2 b	87.5 b	9.8 b	30.0	2.7 b	72.8 a	8.8 a	30.7	3.0 b	72.3 a	8.9 a
4	14.8	0.5 c	120.0 c	12.1 c	29.5	2.6 c	73.3 ab	8.6 b	30.7	4.3 c	72.0 a	8.8 a
8	9.2	0	...	...	29.1	2.5 d	73.0 a	8.8 a	30.6	4.4 d	71.0 a	8.8 a
16	7.3	...	...	...	28.6	2.2 a	74.0 b	8.2 c	30.6	4.3 c	70.0 b	8.5 b
24	5.8	...	...	...	27.5	1.9 e	74.5 ab	8.0 d	30.6	4.3 cd	68.0 c	7.5 c
48	5.8	...	...	...	25.5	1.6 f	72.1 a	7.4 e	30.4	4.4 d	53.0 d	6.3 d
72	5.8	...	...	...	23.6	1.2 g	70.6 d	7.0 f	30.5	4.4 d	31.0 e	4.8 e
SE		±0.04	±0.79	±0.10	...	±0.03	±0.33	±0.04	...	±0.03	±0.36	±0.04
df		15	6	6	...	40	14	14	...	40	14	14

[a] WB = measured on a Warner Bratzler shear press.
[b] Means in the same column followed by different letters differ significantly ($P < 0.05$).

TABLE II
Changes in the Organoleptic Quality of Chapaties Stored in Different Packaging Materials

Storage period (hr)	Waxed Paper			Polyethylene Pouch		
	Eating Quality	Aroma and Taste	Overall Quality	Eating Quality	Aroma and Taste	Overall Quality
0	Soft	Typical wheaty	Good	Soft	Typical wheaty	Good
2	Soft	Typical wheaty	Good	Soft	Typical wheaty	Good
4	Soft	Moderately typical wheaty	Satisfactory	Soft	Moderately typical wheaty	Satisfactory
24	Soft	Moderately typical wheaty	Satisfactory	Slightly tough and brittle	Slightly bland	Satisfactory
48	Moderately tough	Slightly bland	Fair	Slightly tough and brittle	Bland	Satisfactory
72	Moderately tough, slightly brittle	Bland	Fair	Slightly tough and brittle	Mild off-flavor	Fair

hr of storage (Table II). In addition, the eating quality of this chapati deteriorated to some extent after the storage period, as indicated by the slight decrease in WB shear value (Table I). The chapati stored in the polyethylene pouch had become slightly tough and brittle after 24 hr of storage, and after 72 hr of storage it had a mild off-flavor (Table II).

Chemical Characteristics

Changes in some chemical characteristics of chapati stored in polyethylene are presented in Table III. The ether extractives and salt-soluble proteins remained unchanged during storage. Similar negligible changes have also been reported during storage of bread (Maga 1975). Total reducing sugars, however, changed gradually from 406 to 347 mg%, and damaged starch decreased considerably (from 23.3 to 9.8%) after three days of storage. These results indicated a decrease in the enzyme-susceptible starch in stored chapati. Bice and Geddes (1955) reported that retrograded starch was not acted upon by diastatic enzymes. Hence, it could be inferred that retrogradation of starch might be the reason for the decrease in enzyme-susceptible starch. Similar observations have been reported for bread (Maga 1975, Schoch 1965, Hertz 1965).

The change in starch characteristics of chapati during storage was also confirmed by the decreased water retention capacity (from 365 to 200%) as well as by decreased falling number values (472 to 150). Among the different fractions, soluble amylose decreased markedly from 0.23 to 0.02% within three days' storage. On the other hand, amylopectin decreased gradually as the storage period increased. This suggested that both soluble amylose and amylopectin are involved in the development of brittleness in chapati, similar to their involvement in the crumbliness of bread.

Mold growth

Mold growth was observed in chapati stored in a polyethylene pouch after three days. However, for chapati stored in waxed paper, the onset of mold growth was delayed by 12 hr, probably due to the loss of about 7% moisture. The unwrapped chapati was free from mold, as its low moisture content (5–6%) was not conducive to mold growth. Kameshwara Rao et al (1964) also reported a storage life of only three days for chapati packed in either a heat-sealed polyethylene pouch or an aluminum foil/polyethylene laminate.

TABLE III
Changes in the Chemical Characteristics of Chapati During Storage in Polyethylene Pouches[a]

Storage Period (days)	Salt-Soluble Proteins (%)	Ether Extractives (%)	Reducing Sugars (mg%)[d]	Damaged Starches (%)	Diastatic Activity (mg/10 g flour)	Water Retention Capacity (%)	Falling Number	Soluble Starches (%)	Soluble Amylose (%)	Soluble Amylopectin by Difference[c] (%)
0	1.01 a[b]	1.02 a	406 a	23.3 a	398 a	365 a	472 a	2.11 a	0.23 a	1.88 a
1	1.08 a	1.03 a	390 b	16.8 b	396 a	336 b	427 b	1.70 b	0.22 a	1.48 b
2	1.08 a	1.04 a	382 b	10.5 c	280 b	269 c	203 c	1.12 c	0.04 b	1.08 c
3	1.04 a	1.07 a	347 c	9.8 d	252 c	200 d	150 d	1.02 d	0.02 b	1.00 d
SE (12 df)	±0.02	±0.03	±3.54	±0.12	±4.01	±4.62	±2.93	±0.02	±0.01	±0.02

[a]Values are expressed on a 14% moisture basis. Each value is the mean of four observations.
[b]Means of the same column followed by different letters differ significantly ($P < 0.05$).
[c]Values were obtained by subtracting percent soluble amylose from percent soluble starches.
[d]Milligrams (as maltose) per 100 g sample.

TABLE IV
Effect of Heat Treatment[a] on the Quality of Chapaties

Heat treatment (min)	No. Days Stored Moldfree	Eating Quality	Aroma and taste	Overal Quality	Tearing Resistance[b] (g)
0 (Control)	3	Slightly brittle	Mild off-flavor	Fair	33
10	4	Slightly brittle	Mild off-flavor	Fair	30
20	4	Slightly brittle	Mild off-flavor	Fair	32
30	4	Slightly brittle	Mild off-flavor	Fair	27
40	6	Slightly tough, brittle	Bland	Satisfactory	26
50	9	Slightly tough, brittle	Bland	Satisfactory	22
60	16	Slightly tough, brittle	Mild cooked flavor	Fair	16
90	90	Very tough and brittle	Cooked flavor	Poor	5

[a]Chapaties were packed in polyethylene pouches and heated at 90°C.
[b]Tearing resistance of fresh chapati: 72 g.

TABLE V
Effect of Additives and Ingredients on the Quality of Chapaties

Additives and Ingredients: Used	Additives and Ingredients: Level (%)	No. Days Stored Moldfree	Eating Quality	Aroma and Taste	Overall Quality	Tearing Resistance (g)
Nil	...	3	Slightly brittle	Mild off-flavor	Fair	32
Salt	1.25	3	Soft	Moderately typical wheaty	Fair	33
Fat	4.0	3	Soft	Bland	Fair	33
Salt + fat	1.25 + 4.0	4	Soft	Moderately typical wheaty	Satisfactory	38
Sorbic acid	0.2	4	Soft	Bland	Fair	32
Sorbic acid + salt + fat	0.2 + 1.25 + 4.0	5	Soft	Moderately typical wheaty	Satisfactory	31
Sorbic acid + salt + fat + glycerol monostearate	0.2 + 1.25 + 4.0 + 0.5	5	Very soft	Moderately typical wheaty	Good	45

Improvement in the Shelf Life of Chapati Through Heat Treatment

Heating chapaties packed in polyethylene pouches for different periods showed that heating at more than 90°C resulted in excessive condensation of moisture and softened the pouch. The chapati quality as well as the number of days the chapati remained moldfree during storage is shown in Table IV. Evidently, increasing the duration of heat treatment prolonged the period during which the chapati was free from mold. Heating the packaged chapati for 50 min delayed the onset of mold growth by nine days. The efficacy of heat treatment improved considerably when heating periods exceeded 60 min. The mold growth appeared only after 90 days when the chapati was heated for 90 min, but the overall quality of chapati was poor. When a chapati was heated for 10–40 min, tearing resistance, which reflected brittleness, was not much affected during storage. The tearing resistance of chapati decreased considerably (from 33 to 5 g) when heat treatment was given for 90 min.

Effect of Some Additives and Ingredients on the Quality of Stored Chapati Packed in Polyethylene Pouches

Addition of optimum levels of salt or fat did not delay the onset of mold growth, but chapati eating quality was slightly better as compared to controls (Table V). The mild off-flavor observed in the control chapati was not observed in chapati containing salt or fat. Use of both salt and fat further improved the eating quality as well as flavor of stored chapaties. Inclusion of 0.2% sorbic acid, in addition to salt and fat, delayed mold growth by a day (as compared to control) but did not improve textural characteristics. Use of glycerol monostearate at 0.5%, along with sorbic acid, salt, and fat, considerably improved the eating quality of stored chapati, as indicated by the increase in tearing resistance from 32 g for control to 45 g for the experimental samples. Further, the overall quality of stored chapati was good.

CONCLUSIONS

The results of different studies indicated the possibility of objectively measuring changes in the quality of stored chapati by using the tearing resistance tester, WB shear press, and a newly devised pliability tester. Tearing resistance values reflected the brittleness, and WB shear values indicated the texture of chapati. The studies also showed that changes in the characteristics of starch are responsible for adverse changes in chapati simulating those during staling of bread.

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