Effect of Damaged Starch on the Chapati-Making Quality of Whole Wheat Flour

P. HARIDAS RAO, K. LEELAVATHI, and S. R. SHURPALEKAR[1]

ABSTRACT

Effect of damaged starch on the functional quality characteristics of whole wheat flour used for chapati making was studied. Damaged starch in the flour was positively correlated to the diastatic activity ($r = 0.884$, $P < 0.01$) and chapati water absorption ($r = 0.955$, $P < 0.001$) and negatively correlated to the percentage overtailings on a 10 XX sieve ($r = -0.938$, $P < 0.001$). The various rheological characteristics of whole wheat flour were also influenced by the damaged starch as indicated by its significant correlation to dough development time ($r = -0.924$, $P < 0.001$), extensibility ($r = 0.883$, $P < 0.01$), resistance to extension ($r = 0.899$, $P < 0.001$), cohesiveness ($r = 0.835$, $P < 0.01$), and adhesiveness ($r = 0.732$, $P < 0.01$). The flour with damaged starch in the range of 14.1–16.5% was considered to be optimum, as it yielded chapaties with better pliability, texture, taste and overall acceptability.

Cereal Chem. 66(4):329–333

Chapati, a flat unleavened baked product and also known as *roti*, forms the staple food item in the diet of a vast majority of over a billion people of the Indian subcontinent. What bread based on refined wheat flour is to the western world, chapati based on whole wheat flour is to the Indian subcontinent. More than 75% of the total wheat production of 45 million metric tons gets processed into whole wheat flour (mainly used for chapati making) in about 300,000 disc mills operating throughout the country.

The quality of chapati is influenced greatly by the quality of wheat used for its preparation (Austin and Ram 1971, Chopra and Bhat 1975, Murthy and Austin 1963). Leelavathi et al (1986) observed that the type of mill used for grinding wheat influenced considerably the quality of chapati and attributed this to the variation in the percentage of damaged starch. Sharma and Bains (1974) and Haridas Rao et al (1987) reported that water absorption of whole wheat flour was mainly influenced by its damaged starch content. Although the influence of starch damage on the quality of bread is quite well established (Tara et al 1972, Pratt 1978, Tipples 1969), little is known about its effect on the quality of chapati. It is against this background that a study of the effect of damaged starch in whole wheat flour on different parameters of chapati dough as well as chapati was undertaken; the results are presented in this paper.

MATERIALS AND METHODS

Wheat

Medium hard *Triticum aestivum* wheat, generally considered suitable for chapati making (Austin and Ram 1971) was procured locally.

Disk Mill

A disk mill, also known as a plate mill (Fig. 1), is a a simple grinding machine that works on the same principle as a laboratory coffee grinder. It consists of two chilled cast iron plates (Brinnel hardness number, 350; diameter, 30 cm; thickness, 20 mm) placed vertically. One of the plates is stationary, while the other rotates at 500 rpm. The plates have about 120 corrugations of 3–4 mm depth. The cleaned grain is fed through a hopper in between the plates and ground into flour by shearing action as well as friction. The flour emerges through the outlet located at the bottom of the plate. The particle size of the flour obtained can be varied by altering the clearance between the plates.

Disk mills are power driven by a 7.5-hp electric motor and have a grinding capacity of 100 kg of wheat per hour. Such a mill costs about 12,000 rupees ($750) as compared to 10 million rupees ($625,000) of a roller flour mill of 4 tons/hr capacity.

Whole Wheat Flour

Five-kilogram lots of cleaned wheat were ground in 15 different disk mills to obtain whole wheat flours with different percentages of damaged starch. Starch damage of the whole wheat flour depends on the sharpness of the plate corrugations and the clearance between the plates. The heat developed in the flour due to severity of grinding was recorded with a thermocouple. The flour samples were cooled immediately and stored in air-tight tin containers. Nine flour samples with varied percentages of damaged starch were selected for further studies.

Sieve analysis, chemical analysis, and evaluation of rheological characteristics were carried out in duplicate; determinations of chapati water absorption, dough extrusion time, and evaluation of quality and shelflife of chapati were carried out in

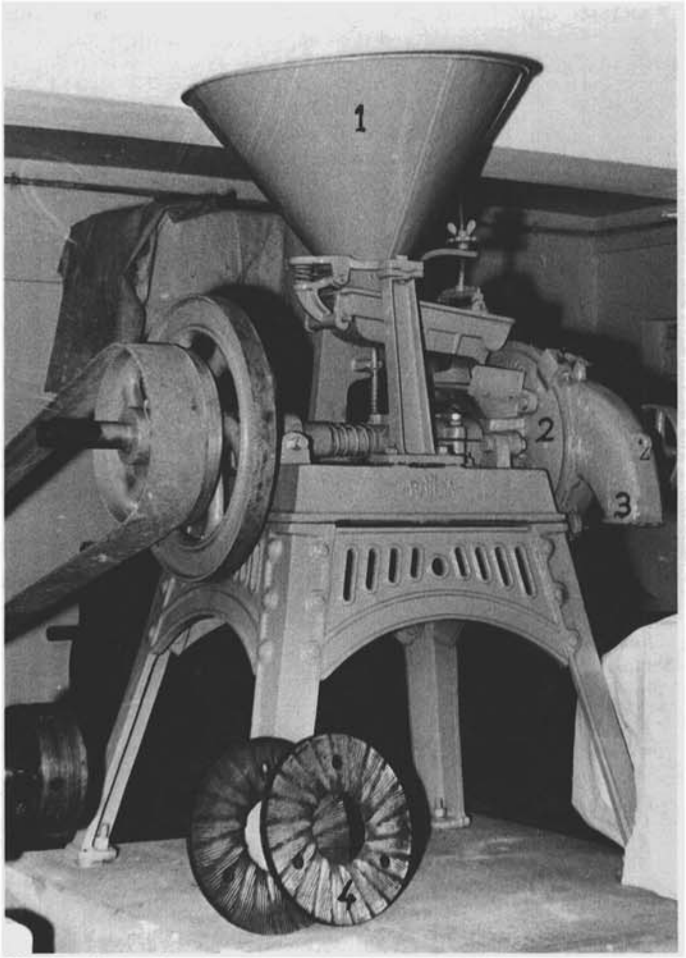

Fig. 1. Disk mill: hopper (**1**), location of grinding plates (**2**), flour outlet (**3**), grinding plates removed from mill for illustration (**4**).

[1]Scientists, Flour Milling and Baking Technology Discipline, Central Food Technological Research Institute, Mysore-570 013, India.

quadruplicate, because these parameters are new and not yet well established.

Sieve Analysis

Sieve analyses of whole wheat flour samples were carried out in a Buhler laboratory Plansifter using 200-g flour samples. The overtailings of each sieve were weighed after 5 min of sieving, and percentages were calculated on a total flour weight basis.

Chemical Analysis

Flour moisture content, diastatic activity, and damaged starch content were determined by standard AACC methods (1976). Total sugars in the chapati dough (referred to under rheological characteristics) were estimated according to an AOAC method (1975).

Rheological Characteristics

Brabender farinograph characteristics were determined at the optimum chapati dough consistency of 450 Brabender units at the 1:3 level position (Haridas Rao et al 1987). For extensigraph studies, the chapati dough was made in a Hobart mixer (model N-50) using farinograph water absorption. In view of its greater stiffness, only 75 g of chapati dough (instead of the 150 g of bread dough normally used) was taken for stretching on the extensigraph. The difference was made up by keeping a 75 g weight on the dough holder (Haridas Rao 1982). The evaluation of farinograms and extensigrams was carried out in accordance with AACC methods (1976).

Consistency of the dough, based on different flour samples and 70% added water (on 14% moisture basis), was determined as extrusion time in seconds using the Research Water Absorption Meter (Henry-Simon Ltd., Stockport, England; Anonymous 1955). Chapati water absorption was also determined using the same instrument, as described earlier by Haridas Rao et al (1987). Water required for obtaining a dough with an extrusion time of 60 ± 5 sec was considered the chapati water absorption.

TABLE I
Sieve Analysis of Whole Wheat Flours of Various Damaged Starch Contents

Flour Sample No.	Damaged Starch (%)	Overtailings on Sieve (%) 10 XX[a]	12 XX[b]	Pan[c]
1	10.6	50.4	39.6	10.0
2	12.0	43.0	39.3	17.7
3	12.5	50.0	28.5	21.5
4	13.7	32.1	45.7	22.2
5	14.1	43.0	48.2	18.8
6	15.5	35.0	54.9	10.1
7	16.5	28.9	52.8	18.3
8	18.0	24.2	58.9	17.9
9	19.6	16.9	69.5	24.6

[a]Sieve opening +129 μm.
[b]Sieve opening +112 μm.
[c]Sieve opening 112 μm.

Textural Characteristics

Textural characteristics of chapati dough were determined using the General Foods Texturometer (model GFT) under the following standard conditions: plunger, 20-mm diameter; aluminum cup; voltage, 1 V; clearance, 2 mm; and low speed.

About 25 g of the dough was placed in a cup. A 2 kg-weight was placed on the cup for 1 min to distribute the dough uniformly, and the excess was removed with a sharp knife. The texturometer curves obtained were evaluated for various parameters, such as hardness, cohesiveness, adhesiveness, and elongation, according to the standard method (Tanaka 1975).

Preparation and Evaluation of Chapati

Chapaties from different flour samples were prepared by the standard test baking procedure of Haridas Rao et al (1986). Using chapati water absorption, the flour was made into a dough in a Hobart mixer. About 35 g of the dough was rolled into a circular sheet 2.5-mm thick, cut into a circle 15-cm in diameter, baked on both sides on a heated iron plate, and then puffed in a gas *tandoor* oven (model Supercook).

Height of chapati on puffing was determined using a centimeter scale, and its pliability was measured on a pliability tester developed for the purpose by Haridas Rao et al (1986). Shear value and tearing resistance of chapati were measured using a Warner-Bratzler shear press and a tearing resistance tester, respectively, according to methods described earlier (Venkateswara Rao et al 1986). Sensory qualities of chapati, such as handfeel, appearance, eating quality, and taste were assessed by a panel of six judges, adopting the procedure described by Haridas Rao et al (1986).

Keeping Quality of Chapati

Four chapaties weighing 27–28 g were packed in waxed paper and stored for 4 hr for assessing the keeping quality with special reference to retention of freshness as influenced by wheat flour starch damage.

Statistical Analysis

The statistical evaluation of the data was carried out according to Duncan's new multiple range test (1955).

RESULTS AND DISCUSSION

Chemical Characteristics

The wheat used for chapati making had the following chemical characteristics (on 14% moisture basis): protein, 9.8%; ash, 1.75%; ether extractives, 2.1%; sedimentation value, 26 ml; and falling number, 360. These parameters were considered suitable for chapati making (Austin and Ram 1971).

Sieve Analysis

Sieve analysis of flour samples with different damaged starch contents is presented in Table I. The data indicated that, in general, the overtailings of the 10 XX sieve decreased while the overtailings of the 12 XX sieve increased with increasing levels of damaged

TABLE II
Physico-Chemical Characteristics of Different Whole Wheat Flours

Flour Sample No.[a]	Temperature (°C)	Moisture (%)	Diastatic Activity (mg/10 g)	Chapati Water Absorption[b] (%)	Extrusion Time[b] (sec)
1	70	10.1	270	71.0 a	62 a
2	76	10.2	300	73.0 b	78 b
3	75	9.4	330	73.5 b	75 c
4	84	9.3	336	75.5 c	90 d
5	89	9.8	340	76.0 d	110 e
6	86	8.1	470	77.5 e	150 f
7	87	8.4	485	79.0 f	169 g
8	88	8.4	490	80.0 f	175 h
9	95	7.5	510	82.5 g	210 i
SEM (27 df)				± 0.23	±1.03

[a]Sample numbers are arranged in order of increasing damaged starch content (Table I).
[b]Determined on a Research Water Absorption Meter. The average values followed by different letters differ at 5% level.

TABLE III
Effect of Damaged Starch Content on the Rheological Characteristics of Different Whole Wheat Flours

Flour Sample No.[a]	Farinograph Characteristics[b] Water Absorption (%)	Dough Development Time (min)	Dough Stability (min)	Extensigraph Characteristics Extensibility, E (mm)	Resistance to Extension, R (BU)	Ratio Figure (R/E)	Area (cm^2)
1	70.4	6.0	5.5	40	600	15.0	29
2	72.8	5.5	5.0	50	680	13.6	34
3	72.2	5.0	5.5	45	650	14.4	36
4	75.0	5.5	4.5	46	700	15.2	35
5	75.5	5.0	5.5	50	700	14.0	20
6	78.0	4.5	5.5	51	730	14.3	38
7	79.0	4.5	5.0	49	700	14.1	33
8	80.0	4.5	4.5	58	730	12.6	36
9	82.5	4.0	5.5	58	770	13.3	49

[a]Sample numbers are arranged in order of increasing damaged starch content (Table I).
[b]At a dough consistency of 450 BU with the lever in the 1:3 position.

TABLE IV
Textural Characteristics of Doughs
Based on Different Whole Wheat Flours

Flour Sample No.[a]	Hardness (kg/V)	Cohesivensss	Adhesiveness (cm^2)	Elongation (cm)
1	3.0	0.60	4.7	1.8
2	3.0	0.68	4.7	1.9
3	2.9	0.70	5.1	1.9
4	3.1	0.70	5.1	2.0
5	3.1	0.69	5.1	2.1
6	3.0	0.72	5.2	2.2
7	3.1	0.71	4.8	2.2
8	3.2	0.72	5.2	2.0
9	2.9	0.75	5.5	2.4

[a]Sample numbers are arranged in order of increasing damaged starch content (Table I).

starch. This may be attributed to the particle size distribution of the flour, which evidently is related to the severity of grinding. The damaged starch was found to be positively correlated with the overtailings of the 12 XX sieve ($r = 0.905$, $P < 0.001$) and negatively correlated to the overtailings of the 10 XX sieve ($r = -0.938$, $P < 0.001$).

Physico-Chemical Characteristics

Physico-chemical characteristics of flours of various damaged starch contents are given in Table II. The temperature of flour from the disk mill also depended on the severity of grinding and increased from 70° C to as high as 95° C, with a concurrent increase in damaged starch from 10.6 to 19.6%. The moisture content of the flour also varied due to differences in the heat developed during grinding. Diastatic activity of flours increased with increase in damaged starch, as the latter serves as a substrate for the amylase. A similar positive relationship between damaged starch and diastatic activity was also reported in refined wheat flour by Tara et al (1972).

The extrusion time (an index of consistency) of doughs made from different flour samples with same amount (70%) of water increased as the damaged starch increased. The extrusion time was only 62 sec for flour with 10.6% damaged starch, whereas it was as high as 210 sec for flour having 19.6% damaged starch. A positive correlation was observed between damaged starch and extrusion time ($r = 0.968$, $P < 0.001$). This showed that, at the same level of water addition, doughs based on flour having more damaged starch yielded a relatively stiff dough, as indicated by the higher extrusion time. Chapati water absorption (on 14% moisture basis) increased with the increase in damaged starch ($r = 0.955$, $P < 0.001$). A similar, significant, positive relationship was reported earlier (Haridas Rao et al 1987). The total sugar content of the chapati dough rested for 30 min (Fig. 2) showed an increasing trend as the damaged starch in the flours increased. It was as high as 7.5% in flour having 19.6% damaged starch compared with 2.7% for flour with 10.6% damaged starch. As expected, a chapati made from flour with higher damaged starch content was sweetish in taste.

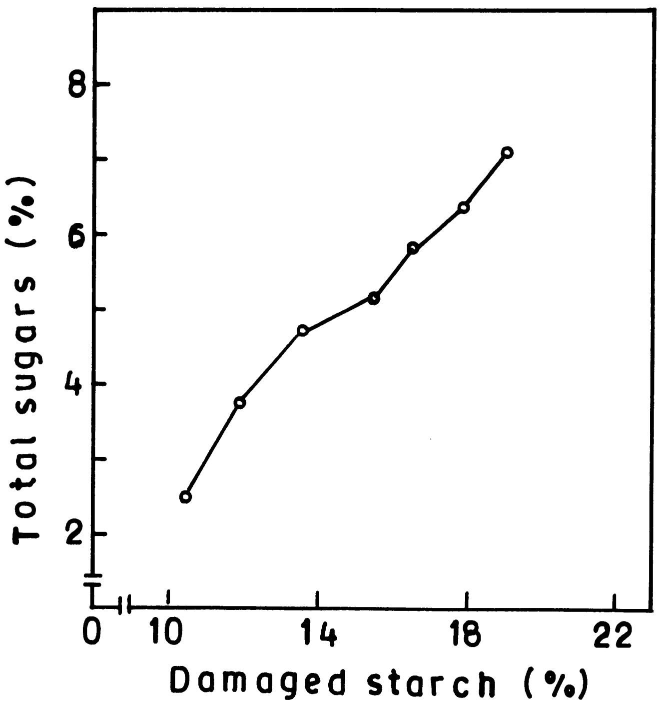

Fig. 2. Effect of damaged starch on the total sugar content of the chapati dough.

Rheological Characteristics

Farinograph and extensigraph characteristics of different flour samples (Table III) showed that farinograph water absorption, like chapati water absorption, increased from 70.4 to 81.5% as starch damage increased, indicating a positive correlation ($r = 0.990$, $P < 0.001$). The dough development time, however, was slightly less for flour samples having a greater proportion of damaged starch. The dough development time was negatively correlated with damaged starch content ($r = -0.924$, $P < 0.001$). Variations observed among values for dough stability did not show any consistent pattern and thus had no correlation with damaged starch in flour samples. Although extensibility and resistance to extension of the dough varied among flour samples, the values did not show marked differences for small variations in the damaged starch content. Both extensibility ($r = 0.883$, $P < 0.01$) and resistance to extension ($r = 0.899$, $P < 0.001$) were postively correlated with damaged starch. The correlation with the ratio of extension resistance to extensibility, however, was negative ($r = -0.667$, $P < 0.05$).

TABLE V
Effect of Damaged Starch Content of Different Whole Wheat Flours on Chapati Qualities[a]

Flour Sample No.[b]	Puffed Height		Pliability		Handfeel (10)[c]	Appearance (20)[c]	Texture (25)[c]	Taste (25)[c]	Total Score[d] (100)[c]
	cm	Score (10)[c]	cm	Score (10)[c]					
1	6.4	8.5 a	1.6	5.2 a	6.1 a	10.5 a	12.4 a	11.1 a	56.8 a
2	6.9	8.8 b	1.8	6.1 b	7.2 b	10.1 b	14.2 b	15.8 b	62.2 b
3	6.0	8.0 c	1.9	6.8 c	7.5 c	12.5 c	12.8 c	15.4 b	63.0 b
4	6.8	8.7 b	1.8	6.1 d	7.0 d	13.8 d	12.9 c	16.2 c	64.5 c
5	7.7	9.6 d	2.0	7.1 e	8.0 e	15.4 e	15.8 d	17.5 d	73.3 d
6	7.9	9.8 e	2.2	7.2 f	8.2 f	16.2 f	16.1 d	17.3 d	75.1 d
7	7.5	9.4 f	2.1	7.3 g	7.8 g	15.1 e	16.3 d	16.8 c	72.8 d
8	6.8	8.7 b	2.1	7.2 g	8.0 e	14.8 g	16.8 e	16.4 c	71.4 e
9[e]	7.9	9.8 e	2.3	7.8 h	8.2 f	10.0 h	16.3 d	17.4 d	69.5 e
SEM (27 df)		±0.04		±0.03	±0.03	±0.15	±0.18	±0.18	±0.44

[a]The average values followed by different letters differ significantly at the 5% level.
[b]Sample numbers are arranged in order of increasing damaged starch content (Table I).
[c]Maximum score.
[d]Total score indicates overall quality.
[e]The dough was slightly sticky.

TABLE VI
Quality Changes During 4-hr Storage of Chapaties Made from Different Whole Wheat Flours

Flour Sample No.[a]	Moisture (%)			Tearing Resistance (lb)			Shear Value (kg)			Total Score[b]		
	0 hr	4 hr	% Change[c]	0 hr	4 hr	% Change[c]	0 hr	4 hr	% Change[c]	0 hr	4 hr	% Change[c]
1	27.5	20.9	24.5 a	40	40	25.9 a	10.5	20.8	21.8 a	56.8	48.8	14.0 a
2	31.1	24.6	20.9 b	63	52	17.4 b	13.4	16.8	25.4 b	62.2	56.3	9.5 b
3	30.7	25.6	16.6 c	66	57	13.6 c	11.8	13.9	17.8 c	63.0	57.0	8.4 c
4	29.8	25.2	15.4 d	68	58	14.7 d	12.5	14.5	16.0 d	64.5	60.1	6.8 d
5	33.8	31.2	10.7 e	70	63	10.0 e	10.8	12.4	14.8 e	73.3	70.1	4.4 e
6	32.7	29.0	11.3 f	75	70	6.6 f	10.3	11.7	13.6 f	75.1	71.8	5.5 f
7	32.3	29.6	8.4 g	75	70	6.6 f	10.6	11.7	10.4 g	72.8	69.9	4.0 e
8	35.2	32.3	9.5 h	78	73	6.4 f	9.3	8.5	8.6 h	71.4	68.1	4.6 g
9	35.7	33.6	5.7 i	80	76	5.0 g	9.3	8.4	9.6 i	69.5	65.4	5.9 f
SEM (27 df)			±0.13			±0.24			±0.29			±0.24

[a]Sample numbers are arranged in the order of increasing damaged starch content (Table I).
[b]Indicates overall quality.
[c]Average values followed by different letters differ significantly at the 5% level.

Changes in rheological characteristics could not be attributed to protein denaturation resulting from heat developed during grinding, since earlier studies showed no change in the protein solubility (Ranga Rao et al 1986). As such, it can be inferred that changes observed were due to starch damage.

Textural Characteristics

The dough characteristics, as measured with a General Foods texturometer (Table IV), indicated little variation in hardness values, because different doughs of the same consistency were obtained using the farinograph water absorption. However, damaged starch had positive correlations with cohesiveness ($r = 0.835$, $P < 0.01$) and adhesiveness ($r = 0.732$, $P < 0.01$). The cohesiveness of a dough is reported to be correlated with the texture of chapati ($r = 0.570$, $P < 0.001$) by Haridas Rao (1982). The increase in dough adhesiveness with increasing damaged starch in flour may be due to the presence of higher amounts of dextrins and sugars formed by the action of amylolytic enzymes on damaged starch. The doughs with higher damaged starch had higher values of elongation ($r = 0.842$, $P < 0.01$).

Chapati Quality

The chapaties made from different flour samples (Table V) indicated that height of chapati on puffing increased with increase in the damaged starch. This may be due to the higher water absorption capacity of these flours allowing formation of more steam pressure during puffing. The chapati was also more pliable. Both the extent of puffing ($r = 0.648$, $P < 0.05$) and pliability ($r = 0.852$, $P < 0.01$) were significantly correlated with the damaged starch content. The brownish spots observed on the surface of baked chapati, however, became undesirably darker at higher levels (16.5%) of damaged starch. In addition, the sheeting of chapati was adversely affected, as the dough tended to become highly sticky when damaged starch in flour exceeded 16.5%. Desirable dough handling, surface color, texture, and taste were observed in chapaties when the damaged starch contents ranged between 14.1 and 16.5%. Consequently, the overall quality score was maximum for these chapaties.

Keeping Quality of Chapati

A good quality chapati should retain its freshness for a minimum of 4 hr (Austin and Ram 1971). The data presented in Table VI show that the loss in moisture during 4 hr of storage varied from 4.1 to 6.5% and was relatively less in chapaties from flours with high damaged starch due to the formation of more dextrins and sugars, which have relatively greater water-holding capacity. The changes in tearing resistance, which indicated the brittleness and shear value and thus the sensory texture (Venkateswara Rao et al 1986), were comparatively less for chapaties made from flours having a higher degree of damaged starch. The total score for overall sensory quality was affected only slightly in chapaties based on flours with higher damaged starch compared with those made from flours with lower damaged starch. The damaged starch was significantly correlated to loss in moisture ($r = -0.928$, $P < 0.001$), decrease in tearing resistance ($r = -0.891$, $P < 0.01$), shear value ($r = -0.904$, $P < 0.001$), and overall quality ($r = -0.752$, $P < 0.05$) of chapati during storage.

CONCLUSIONS

The results of studies have highlighted the importance of damaged starch in wheat flour used for chapati making. Flours containing an optimal proportion (14.1–16.5%) of damaged starch yielded chapaties with better texture, taste, and acceptability.

These results will have considerable relevance in future years, when, like bread, the large-scale mechanized production and marketing of chapaties is likely to become a reality in the Indian subcontinent.

ACKNOWLEDGMENT

The authors thank B. S. Ramesh, scientist, for statistical analysis of the results.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1976. Approved Methods of the AACC. Methods 22-15, 54-10, and 54-21, approved April 1961; Method 44-15A, approved October 1975; Method 76-30A, approved January 1960. The Association: St. Paul, MN.

ANONYMOUS. 1955. Research Water Absorption Meter—Assembly and Operating Instructions. Henry-Simon Ltd.: Stockport, England.

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS. 1975. Official Methods of Analysis, 12th ed. The Association: Washington, DC.

AUSTIN, A. and RAM, A. 1971. Studies on chapati making quality of wheat. Tech. Bull. 31. Indian Council of Agricultural Research: New Delhi.

CHOPRA, K., and BHAT, C. M. 1975. Acceptability of chapaties prepared from high yielding varieties of wheat. Indian Miller 6:38.

DUNCAN, D. B. 1955. The multiple range test. Biometrics 11:6.

HARIDAS RAO, P. 1982. Studies on chapati and similar traditional foods. Ph.D. thesis, University of Mysore, Mysore.

HARIDAS RAO, P., LEELAVATHI, K., and SHURPALEKAR, S. R. 1986. Test baking of chapati—Development of a method. Cereal Chem. 63:297.

HARIDAS RAO, P., LEELAVATHI, K. and SHURPALEKAR, S. R. 1987. Objective measurement of the consistency of chapati dough using "Research Water Absorption Meter." J. Texture Stud. 17:401.

LEELAVATHI, K., HARIDAS RAO, P., and SHURPALEKAR, S. R. 1986. Studies on the functional characteristics of differently milled whole-wheat flour. J. Food Sci. Technol. 23:10.

MURTHY, C. S., and AUSTIN, A. 1963. Studies on the quality characteristics of Indian wheats with reference to the mixability of their flours with the flours of other food grains and tubers for making chapaties. Food Sci. 13:64.

PRATT, D. B. 1978. Page 217 in: Wheat Chemistry and Technology. Y. Pomeranz, ed. Am. Assoc. Cereal Chem.: St. Paul, MN.

RANGA RAO, G. C. P., HARIDAS RAO, P., LEELAVATHI, K., and SHURPALEKAR, S. R. 1986. Effect of heat developed during grinding wheat in a disc mill, on some chemical, rheological and chapati making characteristics of flour. J. Food Sci. Technol. 23:29.

SHARMA, H., and BAINS, G. S. 1974. Damaged starch content of whole wheat meal in relation to maltose value and water absorption. Starch/Staerke 26:378.

TANAKA, M. 1975. General food texturometer applications to texture research in Japan. J. Texture Stud. 6:101.

TARA, K. A., FINNEY, P. L. and BAINS, G. S. 1972. Damaged starch and protein contents in relation to water absorption of flours of Indian wheats. Starch/Staerke 24:342.

TIPPLES, K. H. 1969. The relation of starch damage to the baking performance of flour. Baker's Dig. 43:28.

VENKATESWARA RAO, G., LEELAVATHI, K., HARIDAS RAO, P., and SHURPALEKAR, S. R. 1986. Changes in the quality characteristics of chapati during storage. Cereal Chem. 63:131.

[Received November 3, 1988. Revision received March 22, 1989. Accepted March 28, 1989.]