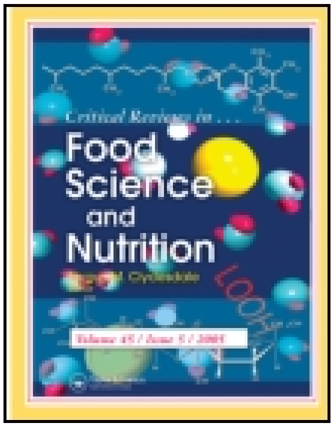


Critical Reviews in Food Science and Nutrition
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/bfsn20

# Wheat-Based Traditional Flat Breads of India

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Accepted author version posted online: 14 Jun 2013.Published online: 08 Aug 2014.

To cite this article: K. R. Parimala & M. L. Sudha (2015) Wheat-Based Traditional Flat Breads of India, Critical Reviews in Food Science and Nutrition, 55:1, 67-81, DOI: 10.1080/10408398.2011.647121

To link to this article: http://dx.doi.org/10.1080/10408398.2011.647121

*Critical Reviews in Food Science and Nutrition*, 55:67–81 (2015)

ISSN: 1040-8398 / 1549-7852 online
DOI: 10.1080/10408398.2011.647121



# Wheat-Based Traditional Flat Breads of India

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*Wheat forms the basic ingredient for various bakery and traditional products. Wheat-based flat breads are one of the traditional products prepared in different parts of the world. Different regions of the world have inherited different preparation methods since time immemorial, which has led to the existence of traditional flat breads'. Being traditional, only a few have been extensively studied scientifically. India, being the second largest producer of wheat, has a great saga of traditional flat breads with different tastes and texture. This review is a compiled information related to the research studies carried out on some of the wheat-based traditional flat breads of India namely chapati, puri, tandoori roti, parantha (whole-wheat flour based) and parotta, naan, bhatura, kulcha (refined wheat flour based) which indicates the magnitude of attention they have drawn among the food scientists. The review delves upon the developments and improvements brought about in the storage stability and realization of large-scale production of few of these flat breads which has helped considerably to cater to the growing demand in the domestic as well as international markets. The review also indicates the possibility and the tremendous scope available for technological developments for traditional flat breads.*

**Keywords** Wheat, traditional flat breads, chapati, puri, parotta, naan, bhatura, kulcha

## *INTRODUCTION*

Wheat is one among the different cereals grown all over the world. It is the basic raw material for bakery and household food products and needs to be pulverized into fine flour before preparing different end-products. The quality of flour determines its suitability for a particular product. Mainly, wheat is processed into refined wheat flour in roller mills and becomes the basic raw material for production of bread, cakes, biscuits, cookies, crackers, breakfast cereals, noodles etc. Wheat is also processed into whole-wheat flour in chakki/plate mills and is used in the preparation of traditional flat breads like *chapati, puri, tandoori roti* etc.

## *TRADITIONAL FOODS*

Foods which are typically produced and consumed in certain local areas where they have greater acceptance due to their characteristic color, flavor and texture are called as traditional foods. According to European Union, it is a food of a specific feature or features, which distinguish it clearly from other similar products of the same category in terms of the use of traditional ingredients or traditional composition or traditional type of production or processing method. Traditional foods reflect the cultural inheritance and have left their imprints on contemporary dietary patterns. The large number of traditional products is logical, taking into account the diversity of cultures and varied climatic conditions. Food enterprises recognized a potential profit in the increased contemporary demand for traditional foods by health conscious consumers. Therefore, important issues of registration and standardization of traditional foods have arisen for these products: (1) to protect against imitations, (2) to ensure high quality and (3) to conform to contemporary rules of appropriate and safe production. Prior to Second World War, people applied simple and time-honored approaches for food production. But with the advancement of technological innovations during post-war era, mass food production started, that substantially altered the food production processes. In India, some of the mass food production processes still rely on traditional manufacturing practices with low competitiveness and poor efficiency. The final goal is to achieve a consistent and regular quality while also meeting consumer demands for safe and hygienic nutritional foods. An update of the knowledge on traditional

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foods, especially on the developments will contribute to meet the challenges for the improvement of traditional foods. Recent developments and trends in areas like processing technology and engineering, quality, hygiene, and safety and nutritive value of traditional foods are important. Scientific investigations of traditional foods contribute towards the improvement in mass production technology as well as for the preservation of important elements of a nation's heritage and culture. It would also enrich and improve the diet pattern of the populations across the country. This is an overview of the flat breads of the world with particular emphasis on Indian flat breads and the scientific literature being reviewed latter.

## *FLAT BREADS*

Flat breads were the earliest breads made by humans. Ingredients like flour, water, and salt were kneaded into pliable dough before being shaped by hand and baked. Flat breads were eaten at every meal, functioning as plates with other foods being served on them or as implements for eating other things such as stews or sauces. They are important amongst the people of India and the Middle East and have spread to Western countries where their popularity is growing because of their versatility. They can wrap (tortilla), hold (pita), and form the base of substantial foods (pizza).

## *POPULAR FLAT BREADS OF THE WORLD*

People have been making flat breads for well over 6000 years. The oldest baker's oven in the world was known in Babylon in 4000 B.C. Flat bread was baked in hot ashes or on heated stone slabs in the old kingdom of Egypt as long ago as 4000 B.C. Next discovery was baking the flat sheets of dough on flat stones in hot sun by nomadic herdsmen. Tandoor originated in Persia (Iran) and brought to India via Afghanistan by Arabs way back in 3000 B.C. Small mud-plastered ovens have been found in Harappa and Mohenjo-Daro of ancient valley.

Description regarding the popular flat breads (www.wheatfoods.org; www.ndwheat.com) of the world is presented in Table 1. *Injera* (Ethiopia, Somalia, and Eritrea) is a traditional, staple Ethiopian bread made with teff flour similar to pancake or crumpet and used as a wrapper. *Khubz* (Morocco), in the Arabian Peninsula region, refers to large flat bread baked in a special oven often called a "tannuur." The dough is rolled out like pizza dough and positioned on a round board and slapped on to the inside wall of the large round stone oven. *Ngome* (Mali) is made out of millet, water, and vegetable oil.

### *Mediterranean/Middle East*

*Aish Mehahra* (Egypt) is made with 5 to 10% ground fenugreek seeds and maize; *Baladi* (Egypt) a traditional Egyptian pita bread is either made with wheat flour (*Aesh Baladi and Aash Makamar*) or whole-wheat flour (*Aash Baladi*). It is a pocket bread that has various uses such as kebab wrap, sandwich bread, or as a spoon, etc.; *Barbari bread* (Iran) is a type of Persian flatbread originally brought to Iran by Hazara migrants in the 19th century, referred to by Iranians as Barbars. This is most commonly baked in Afghanistan; *Lavash* (Armenia) a paper thin traditional bread often dried and re-hydrated before use; *Matzo* (Israel) is a very thin bread with a cracker-like texture prepared in Israel; *Pita* is made with a mixture of flour, salt, yeast, and water. Fermentation time is short so that the dough does not rise and when baked, the heat quickly seals the top and bottom surfaces and the rapid expansion of gases between them tends to blow the crusts apart forming the pocket; *Sangak* (Iran) is a traditional and staple flat bread made of whole-wheat flour and baked on hot pebbles.

### *China*

*Green onion pancakes* is made with all purpose flour, oil, and minced scallions (green onions); *Sanchuisanda* is baked in ashes.

### *Southeast Asia*

*Khanom buang* (Thailand)is made with rice flour; *Roti canai* (Malaysia) is a type of flat bread prepared in Malaysia, often sold in Mamak stalls. It is known as roti prata in Southern Malaysia and Singapore, and is similar to the Indian Kerala porotta. *Roti canai* is circular and flat.

### *Europe*

*Blintz/blini* (Russia) is a thin pancake which is somewhat similar to a crepe with the main difference being the fact that yeast is used in blintzes, but not in crepes; *Ciabatta* (Italy) is an Italian white bread made with wheat flour and yeast and was developed in 1982. The loaf is somewhat elongated, broad, and flat like a slipper, and somewhat collapsed in the middle. Since the late 1990s, it is popular across Europe and the United States, and is widely used as sandwich bread. *Crepes* (France) is a very thin pancake usually made from wheat flour. The word crepes are of French origin, derived from the Latin *crispa*, meaning "curled." While *crêpes* originated from a region in the Northwest of France and consumed throughout in France. Crepes are considered as a national dish and are also popular in North America and South America; *Flat bread* (Norway) is made with barley flour, salt, and water; *Focaccia* (Italy) is a traditional Italian bread, is also known as cousin of pizza, has various flavors and shapes such as the focaccia salvia, schiacciata in Tuscani. Each region of Italy has its own local recipe; *Pizza* (Italy) is a traditional Italian thin bread cooked on a very

**Table 1** Popular flat breads of the world

| Region | Country | Name | Description | Ingredients |
|---|---|---|---|---|
| Africa | Ethiopia/Somalia/ Eritrea | *Injera* | Similar to pancake or crumpet | Teff flour |
| | Morocco | *Khubz* | Rolled like pizza | |
| | Mali | *Ngome* | Flat bread | Millet, water, and vegetable oil |
| Mediterranean/ Middle east | Egypt | *Aish Mehahra* | Flat bread | 5–10% fenugreek seeds and maize |
| | | *Baladi* | Pocket bread/sandwich bread | Wheat flour/whole wheat flour |
| | Iran | *Barbari* | Persian flat bread | Wheat flour |
| | Armenia | *Lavash* | Paper thin and rehydrated before use | Wheat flour |
| | Israel | *Matzo* | Thin bread with cracker like texture | Wheat flour |
| | | *Pita* | Flat bread with less fermentation time | Flour, salt, yeast, and water |
| | Iran | *Sangak* | Flat bread | Whole-wheat flour |
| Southeast Asia | Thailand | *Khanom buang* | Flat bread | Rice flour |
| | Malaysia/Singapore | *Roti canai* | Circular and flat | Wheat flour |
| Europe | Russia | *Blintz/blini* | Thin pancake | Wheat flour |
| | Italy | *Ciabatta* | Elongated white bread, flat like a slipper and collapsed in the middle | Wheat flour, yeast |
| | | *Focaccia* | Cousin of pizza with different flavors and shape | Wheat flour, yeast etc. |
| | | *Pizza* | Thin bread | Wheat flour, yeast, etc. topped with tomato sauce, olive leaves, and mozzarella cheese. |
| | Norway | *Lefse* | Cooked on a griddle | Flour, potato, milk, and cream |
| North America | | *Pancake* | Thin flat prepared from a batter | Either yeast raised or fermented batter |
| South and Central America | | *Arepa* | Flat unleavened patty | Cornmeal |
| | Mexico | *Tortilla* | Flat unleavened bread with crisp texture | Corn flour or wheat flour |
| India/Sri Lanka | | *Bhakri* | Flat unleavened bread | Sorghum flour, water, and oil |
| | | *Dosa/Dosai* | Flat leavened bread | Rice flour, blackgram, and salt |
| | | *Chapati/phulka* | Flat unleavened bread | Whole-wheat flour, salt, and water |
| | | *Tandoori roti* | Flat unleavened bread baked on a tandoor | Whole-wheat flour, salt, and water |
| | | *Parantha* | Flat bread folded with ghee | Whole-wheat flour, salt, and water |
| | | *Puri* | Deep fat fried | Whole-wheat flour, salt, and water |
| | | *Naan* | Flat bread baked on a tandoor | Wheat flour, salt, yoghurt, and water |
| | | *Parotta* | Creamish colored flat bread with distinct layers | Wheat flour, oil, salt, and water |
| | | *Kulcha* | Creamish colored flat bread | Wheat flour, oil, curd, yeast, salt, sugar, and water |
| | | *Bhatura* | Deep fat fried | Wheat flour, oil, yoghurt, soda, yeast, salt, sugar, and water |



hot stone oven (900-F/450-C), topped with tomato sauce, olives, and Mozzarella cheese; *Lefse* (Norway) is made using potato, milk or cream (sometimes lard), and flour and cooked on a griddle.

### *North America*

*Pancake* is a thin, flat cake prepared from a batter and cooked on a hot griddle or frying pan. Most pancakes are quick breads; some use a yeast-raised or fermented batter. Most pancakes are cooked one side on a griddle and flipped partway through to cook the other side.

### *South and Central America*

*Arepa* is a flat, unleavened patty made of cornmeal; *Tortilla* is a mexican unleavened flat bread made from corn flour or wheat flour. They can be soft or crisp, depending on how long they are baked. When they are soft, they are used as burritos and when crisp are served as tostadas or corn chips.

### *India and Sri Lanka*

*Nonwheat-based products: Bhakri* is made primarily with sorghum flour, water, and oil; *Dosa or Dosai* is made from rice flour, black gram flour, and salt; *Pappad* is a thin Indian crispy cuisine sometimes described as a cracker or flatbread. They are typically served as an accompaniment to a meal in India. It is also eaten as an appetizer or a snack and can be eaten with various toppings such as chopped onions, chutney, or other dips and condiments.

*Wheat-based products:* Among the traditional products, wheat-based flat breads of India are *chapati, puri, tandoori roti,* *parantha, South Indian parotta, naan, bhatura*, and *kulcha* prepared from either whole-wheat flour or wheat flour. *Naan* is a traditional Indian flat bread, enriched with yoghurt baked in the traditional Indian oven, the tandoor. It is the usual accompaniment of hot food and is staple food in most parts of India. There are various types of the *naan* such as the *Peshwari naan* (filled with nuts and raisins), *Kema naan* (stuffed with minced meat), or *Kashmiri naan*, etc.; *Chapati* is made from atta, water, and salt; *Parantha* is an Indian flat bread which is smeared and folded with ghee, rolled, and layered; *Puri* is a traditional Indian deep-fried, puffed bread used as a shell to be filled with sweet or hot and spicy savoury fillings; *Khakra* are rotis roasted to dry out completely and made crispy.

A brief report of the scientific studies enlightening different properties, qualities, and the greater potential of commercialization of these flat breads have been discussed for the interest of food scientists and processors.

## *WHOLE-WHEAT FLOUR-BASED FLAT BREADS*

### Chapati

Bulk of the wheat produced in India is milled by power-driven chakkies. The process results in 15 to 17% starch damage without the loss of ash. The whole-wheat flour (atta) obtained from these mills is widely used in the preparation of traditional wheat products. *Chapati* is an unleavened, circular-baked product prepared from whole-wheat flour (commonly known as atta), which is the staple food of a majority of the population in many regions of the Indian subcontinent and parts of the Middle East (Nurul et al., 1987). About 80 to 85% of the total wheat produced in the country is used for the preparation of *chapati* (Misra, 1998).

#### *Factors Influencing the Quality Characteristics of* Chapati

The quality of *chapati* is influenced greatly by the quality of wheat (Austin and Ram, 1971; Chopra and Bhat, 1975; Leelavathi and Haridas Rao, 1988). There are large differences in grain quality requirements for the major baked products such as bread, pastries, and cookies, and within each of the types the grain quality required to produce flat bread, like Indian *chapati* is different from that required to produce pan-type bread (Pena, 1998). Conditions for preparation of *chapati* with respect to recipe, dough consistency, thickness, size, shape of the dough sheet, and baking conditions vary widely in different regions and laboratories (Austin and Ram, 1971; Shurpalekar and Prabhavathi, 1976). Consequently, the *chapati*-making quality of given wheat may be assessed differently by different investigators. To remove these ambiguities, a standard test baking method has been developed by Haridas Rao et al. (1986), considering different variables such as consistency, rolling characteristics, thickness of the sheet, time and baking temperature, puffing conditions etc. The soft texture, wheatish colour and flavour and slightly sweetish taste are recognized as desirable quality attributes of good quality *chapaties*. The height of puffed *chapati* (complete and fully puffed), softness and pliability served as simple indices of *chapati* quality. Highly significant correlation was obtained between *chapati* water absorption (CWA) and damaged starch ($r = +0.89$) and a significant correlation between water absorption and protein content of the flour ($r = +0.53$). Similarly, (Table 2) the consistency measured in research water absorption meter (RWAM) significantly correlated to farinograph consistency ($r = +0.97$), and texture hardness ($r = +0.96$), whereas, % overtailings of 10XX sieve negatively correlated to water absorption ($r = -0.79$). A multiple regression equation was derived for CWA based on particle size, protein content (Nx5.7) and damaged starch as $Y = 57.96–0.06\ X_1 + 0.52\ X_2 + 1.03\ X_3$, where, $Y$ = CWA (%), $X_1$ = particle size (% of +10XX sieve), $X_2$ = protein content (%) and $X_3$ = damaged starch (%) (Haridas Rao et al., 1986a, 1986b). Some Indian aestivum varieties like Raj-842, D-134, K-68, WG-377, Raj-85, Raj-821, and DGPR-LB gave excellent *chapaties* (Shurpalekar et al., 1976). The intervarietal differences in gluten characteristics were found to be related to gluten composition (Orth and Bushuk, 1972; Huebner and Wall, 1976; Ram and Nigam, 1982). They reported that the viscoelastic property of dough, which influences the baking quality of wheat flour, depends on the quality and quantity of protein. Thus, the ideal wheat cultivar for *chapati* making should have protein content between 10 and 13% (Austin and Ram, 1971).

**Table 2** Interrelationship among flour characteristics, water absorption and chapati dough characteristics

| Variable parameters | Coefficient of variation |
|---|---|
| CWA vs. protein content* | +0.53 |
| CWA vs. damaged starch** | +0.89 |
| CWA vs% over's of sieves** | −0.79 |
| Extrusion time vs. farinograph consistency[a]** | +0.97 |
| Extrusion time vs. texture hardness** | +0.96 |

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.
[a]In lever position 1:3.
*Source*: Haridas Rao et al. (1987).

Wheat with good *chapati*-making quality exhibited distinct electrophoretic pattern (Prabhasankar, 2002). The qualitative differences in wheat proteins appear to outweigh quantitative differences in determining baking quality (Dexter and Matsuo, 1978). The puffed height and the overall quality score of *chapati* were positively correlated with protein content, gluten content, sodium dodecyl sulphate (SDS) sedimentation value, and Glu-1 quality scores of high-molecular weight subunits (Srivastava et al., 2003). It is concluded that cultivars having 5+10 subunits at the Glu-1D chromosome, a protein content of about 130 g/kg and SDS sedimentation value around 75 mL yielded excellent *chapaties*. Wheat proteins and their fractions such as soluble proteins (albumins and globulin), gliadin, and glutenin were isolated and quantified from some wheat varieties. Wheat low in gliadin content yielded poor quality *chapati*, whereas albumin and globulin did not play a significant role in governing the quality of *chapati*. An experiment was conducted to study

**Table 3** Flour characteristics suitable for chapati making

| Characteristics | Optimal values |
|---|---|
| Moisture (%) | 7–9 |
| Total Protein (%) | 10–15 |
| Gliadin (%) | 2.9–3.6 |
| Glutenin (%) | 2.7–3.3 |
| Reducing sugars (%) | 2.8–3.0 |
| Damaged starch (%) | 10–12 |
| Farinograph water absorption (%) | 65–70 |
| Falling number | 400–430 |
| Dough stability(min) | 1.5–3.0 |
| Resistance to extension (BU) | 200–350 |
| Extensibility (mm) | 75–120 |

*Source*: Hemalatha et al. (2007) and Leelavathi and Haridas Rao, (1988).

**Table 4** Effect of heat developed during grinding on flour and chapati quality

| Parameters | Control | Cooled immediately | Cooled slowly |
|---|---|---|---|
| Moisture (%) | 10.2 | 6.8 | 7.2 |
| Free Lipids (%) | 1.40 | 1.74 | 1.74 |
| Bound Lipids (%) | 0.99 | 0.73 | 0.72 |
| Salt soluble proteins (%) | 2.5 | 2.8 | 2.7 |
| Gliadin (%) | 4.2 | 4.5 | 4.5 |
| Glutenin (%) | 4.9 | 4.2 | 4.2 |
| Plate count (x$10^3$/g) | 15.3 | 3.9 | 1.5 |
| Puffed height (cm) | 6.0 | 7.1 | 7.2 |
| WB shear (lb) | 8.2 | 5.8 | 6.0 |
| Overall quality | Satisfactory | Good | Good |

*Source*: Ranga Rao et al. (1986).

the protein characteristics and peroxidase activities of different wheat varieties in relation to *chapati*-making quality, and was concluded that the low-molecular weight protein (gliadin) content significantly correlated to overall quality score of *chapati*, whereas Glu-1 score, an indicator of high-molecular weight protein subunit (glutenin) composition, significantly correlated to the texture of *chapati* and the peroxidase activity which had negative influence on the color of *chapati* thereby reducing the overall quality (Hemalatha et al., 2007). A rapid, sensitive, and single test to assess the quality of different Indian wheat varieties and their suitability for *chapati* making was developed. Considering this fact, electrophoretic and immunologically based methods were studied for application in evaluating wheat varieties for *chapati*-making quality by Prabhasankar et al. (2002). SDS-PAGE and dot-blot were used for predicting the *chapati*-making quality of wheat. The wheat varieties having good *chapati*-making quality exhibited distinct pattern in SDS-PAGE and less intense spots in dot-blot assays. The optimum values of different flour properties that make a wheat variety suitable for *chapati* making are listed in Table 3. *Chapaties* prepared from the chakki-milled atta are preferred, as they are more sweet and palatable than those made from roller mill atta. This may be due to the action of diastatic enzymes ($\alpha$ and $\beta$-amylases), which act on starch and produce sugar and thus contribute toward sweetness to *chapaties*. Depending upon the type of mill employed to produce *chapati* flour, a varied degree of starch damage is produced. Degree of starch damage is more in case of chakki mill and hence more sugars are produced. Ranga Rao et al. (1986) studied the effect of heat developed during grinding of wheat in a disc mill and concluded that there was a significant effect on (a) lipids, protein fraction, and diastatic and proteolytic activities, (b) lowered the total microbial load, and (c) improved the quality of *chapati* particularly with respect to flavor (Table 4).

### Chapaties *from Composite Flours*

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 *chapati* and *puri*. Such composite flours are used for improving protein content and nutritive value of wheat flour products. Durum wheat is generally considered the hardest of all wheats. They do not make good bread, as durum gluten is usually weaker than common bread wheat gluten. *Chapaties* from durum wheat flour showed partial puffing, had less soft texture, and had creamish yellow color which reduced its acceptability (Sharma et al., 1999). Traditionally, in some regions of India, aestivum wheats are blended with small quantities of durums. The blends of durum flour with the aestivum flour at different levels have shown that the *chapaties* with 15 to 35% durum flour blend resulted in excellent sweet *chapaties,* which stiffen too early on storage (Prabhavathi et al., 1976). Barley flour and germinated wheat flour incorporated in *chapati* were acceptable (Leelavathi and Haridas Rao, 1988; Anjum et al., 1991; Sood et al., 1992). *Chapati* made from germinated wheat was less pliable and had darker charred spots compared to normal *chapati*. The eating quality of *chapati* made from germinated wheat flour was poor because of harder texture though they had sweet taste (Table 5). Reducing sugars increased in the first two hours of resting in germinated wheat flour dough. *Chapati* from germinated wheat had better texture and overall quality on storage (four days) than control *chapati* (Leelavathi and Haridas Rao, 1988). Addition of barley flour at 20% level to wheat flour increased the extensibility of *chapati* to 12.91 mm, but at higher levels it decreased. *Chapati* containing barley flour showed higher peak force to rupture and energy to rupture, which remained higher after 24 hours of storage (Gujral and Pathak, 2002). Kaur and Hira (1989) 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. Addition of soy flour or rice flour to wheat flour improved the nutritional quality of *chapati* (Rajagopal et al., 1983). Triticale could be blended with wheat at a level of 50% to make *chapaties* (Sekhon et al., 1980). *Chapaties* made from fortified wheat flour with defatted soy flour were acceptable but those made from rapeseed and sunflower seed flours were unacceptable (Jain et al., 2000). Incorporation of soy, peanut, and cotton seed flours at 10% levels increased the protein content of *chapati* by 17, 22, and 27%, respectively, and also increased the available lysine (Bhat and Vivian, 1980).

**Table 5** Quality characteristics of sound and germinated wheat and chapaties

| Characteristics | Sound wheat | Germinated wheat |
|---|---|---|
| Moisture (%) | 8.1 | 9.3 |
| Protein (%) | 9.9 | 10.3 |
| Reducing sugars (%) | 2.8 | 4.3 |
| Falling number (s) | 422 | 62 |
| Chapati water absorption (%) | 68.6 | 59.4 |
| WB shear value (lb) | 8.00 | 12.00 |
| Puffed height (10+) | 8.00 | 6.38 |
| Pliability (10+) | 8.62 | 3.98 |
| Taste (25+) | 14.50 | 18.38 |

*Source*: Leelavathi and Haridas Rao (1988).



### *Storage Stability of* chapati

Generally, *chapaties* are prepared fresh and consumed as they stale rapidly on storage. With rapidly changing lifestyles, changing socioeconomic trends and increasing urbanization and consumerism there is a rising demand for convenience foods, which require minimum or no preparation time, particularly the ready-to-eat (RTE) type of foods. RTE *chapaties* are the latest addition to the species of "convenience foods." 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*. There are two problems that have to be tackled in large-scale *chapati* production. First, the preservation using suitable chemical preservatives may be required to give *chapaties* a reasonable shelf-life. Second, staling will have to be controlled to retain the soft, pliable texture of *chapaties*, thereby ensuring consumer acceptability. Staling in *chapaties* occurs largely because of retrogradation of gelatinized starch (Venkateswara Rao et al., 1986; Sidhu et al., 1988; Jagannath et al., 1999; Indrani and Venkateswara Rao, 2003). Starch retrogradation is a process that occurs when the molecules comprising gelatinized starch begin to reassociate in an ordered structure. In its initial phase, two or more starch chains may form a simple juncture point, which may then develop into more extensively, ordered regions. Ultimately, under favorable conditions, a crystalline order appears (Atwell et al., 1988). During staling, moisture was released from starch and taken up by gluten (Katz, 1928). Senti and Dimler (1960) studied equilibrium relative humidity (RH), and suggested that moisture transfer occurred from starch to gluten. Cluskey et al. (1959) reported a progressive drop in moisture–sorption capacity for starch and lack of change for gluten, indicating a transfer of moisture from starch to gluten during aging.

Addition of 0.75% of glycerol monostearate (GMS) or 0.75% (w/w) sodium stearoyl lactylate (SSL) retards the staling of starch in the *chapaties* stored at 29°C and refrigerated temperature. The percentage reduction of moisture content in GMS-containing *chapati* during storage at 29 °C was less as compared to control samples. This is due to the ability of GMS to form a complex with helical regions of starch, that is, the straight-chain hydrophobic portion of emulsifiers will complex with the helical section of amylase and amylopectin (Nuessli et al., 2000). SSL reduced the water-soluble starch content to 2.69% as compared to control, which was about 5.23%. This change was attributed to the addition of SSL and GMS which reduced the extent of solubilization of starch molecules upon heating in excess water (Ghiasi et al., 1982). The ability of many surfactants is to form complexes with amylase (Mikus et al., 1946; Strandine et al., 1951; Bourne et al., 1960; Osman et al., 1961; Krog and Jensen 1970; Lagendijk and Penning, 1970; Lonkhuysen and Blankstijn, 1974). The higher degree of softness in the emulsified *chapaties* compared to nonemulsified *chapaties* may be because in the emulsified product, the release of soluble starch, a cemented substance between starch granules and gluten strands in the formation of air-cell walls, is minimized, thus forming a softer cell wall (Morad and D'Appolonia, 1980). Among the hydrocolloids, guar gum increased the extensibility of fresh as well as stored *chapati* (Shalini and Laxmi, 2007). The addition of 1.5% (w/w) sorbitol to the *chapaties* retards staling. The addition of sorbitol to the *chapati* kept the *chapati* softer as indicated in the texture values which increased from 138.25 to 282.28 g force when compared to control, where the values increased from 225.13 to 423.19 g force during 10 days of storage period at 29°C (Zobel and Senti, 1959). The addition of 200 ppm of $\alpha$-amylase and 2% (w/w) of maltodextrin gave the antistaling effect to *chapaties* stored at 29°C and refrigerated temperature (Zobel and Senti 1959; Duedhal-Olesen et al., 1999; Nanjappa et al., 1999). The addition of 1% w/w of guar gum also retarded the staling of *chapaties* both at 29°C and refrigerated temperature storage. All the antistaling additives and water, play a role of plasticizer, thereby preventing the rigidity of macromolecular starch and gluten chains which was determined by Dynamic Mechanical Thermal Analysis (DMTA). Upon ageing, the cross links increased which correlates with rate of staling (Jagannath et al., 1999). Kameshwara Rao et al. (1964) reported that *chapaties* can be preserved satisfactorily for seven days with the incorporation of 4% sodium chloride and packed in polyethylene pouch when stored at 24 to 35°C and 70 to 80% RH. They also 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. Addition of sorbic acid to the *chapati* dough did not affect the rate of amylolysis of polysaccharides and protein extractability in water, alcohol, or acetic acid (Vidyasagar and Arya, 1980). They reported that incorporation of sorbic acid as a preservative did not cause any significant changes in the biochemical reactions taking place either during mixing or during baking. Venkateshwara Rao et al. (1986) conducted the objective tests of the stored *chapaties* using tearing resistance tester and Warner Bratzler (WB) shear press. The *chapaties* which were packed in a polyethylene pouch and heat sealed, those wrapped in wax paper and heat sealed, and those stored in a plastic box (1 mm thickness) were evaluated for sensory as well as objective parameters. The organoleptic properties of *chapaties* packed in different packaging material were preserved to a great extent compared to uncovered samples. The tearing

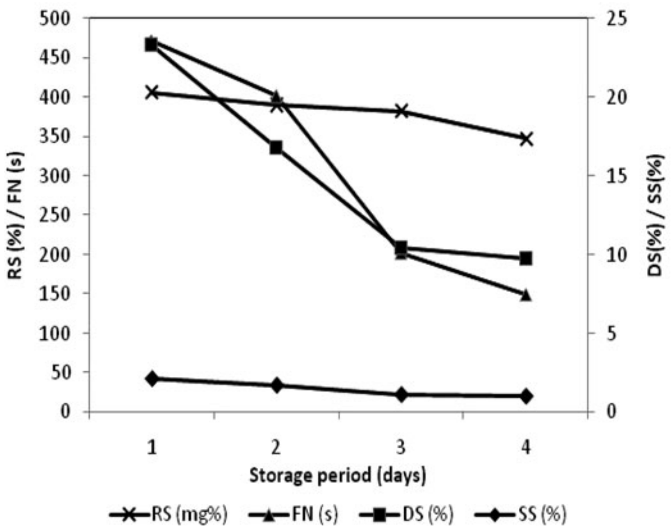


**Figure 1** Changes in quality characteristics of chapati during storage. RS, reducing sugars; FN, falling number; DS, damaged starch; SS, soluble starches. *Source*: Venkateswara Rao et al. (1986).

resistance of stored *chapati* increased considerably from 72.5 to 120.0 g force when kept uncovered for only four hours. The increase in tearing resistance was comparatively lower for the packed *chapaties*. Significant decrease in the WB shear value was observed when the *chapati* was stored in either waxed paper or in a polyethylene pouch as compared to those kept open. *Chapaties* when stored in polyethylene pouches for three days (Fig. 1), showed gradual reduction in reducing sugars from 406 to 347 mg% and damaged starch from 23.3 to 9.8%. Starch characteristics also changed during storage which was confirmed by the decreased water retention capacity (from 365–200%) and falling number (472–150). Among the different fractions, soluble amylose decreased markedly on storage (Venkateshwara Rao et al., 1986).

Gujral and Pathak (2002) studied the tensile properties of *chapati* as affected by composite flours, additives, and also the changes in texture during storage (Table 6). 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. The *chapati* stored for 24 hours was hard and brittle as indicated by the high force values, high modulus of deformation, and short distances of extension before rupture. 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 that occurs in bread (Guy et al., 1983). The use of rice flour to partially replace the wheat flour in *chapati* has been reported (Gujral and Pathak, 2002). Whole-wheat flour was replaced with rice flour at levels of 10 to 50%, which increased the extensibility of the *chapati* but at higher levels of replacement decreased the extensibility. This decrease is attributed to the absence of gluten proteins in the rice flour. Increasing levels of rice flour lead to decrease in both the peak force to rupture, energy to rupture, and modulus of deformation of fresh *chapati*, but after 24 hours 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. *Chapaties* containing corn flour showed lower modulus of deformation as compared to the control sample. *Chapati* containing corn flour remained more extensible and soft even after 24 hours 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 hours of storage, the extensibility remained significantly higher than the control sample. Barley flour contains high levels of $\beta$-glucan, which may be involved in preventing the retrogradation of starch and thus keeping the *chapati* more extensible. *Chapati* containing barley flour showed higher peak force to rupture and energy to rupture, which remained higher after 24 hours 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 hours of storage. Millet flour caused an increase in the peak force to rupture, modulus of deformation, and energy to rupture. Subjects were fed with *chapaties* (Thondre and Henry, 2009) containing high-molecular weight barley $\beta$-glucan at doses of 0, 2, 4, 6, and 8 g on different occasions. Reduction in postprandial blood glucose was observed at 45 minutes when fed with *chapaties* containing 4 g ($P < 0.05$) and 8 g $\beta$-glucan ($P < 0.01$), and at 60 minutes with *chapaties* containing 6 to 8 g $\beta$-glucan ($P < 0.01$).

### *Mechanization of* Chapati *Making*

To cope up with the increasing demand for ready-to-eat *chapaties*, mechanization of *chapati* preparation becomes imperative. In this connection, Sridhar and Manohar (2001) developed and optimized the working of continuous *chapati*-making machine of 4 HP with maximum production capacity of 160 kg/hour of dough extrusion at the optimum moisture content of 65 to 70%. The extruder was a specially designed continuous *chapati*-making system. The process variables were optimized for the continuous production of *chapati* based on minimum-specific energy and maximum-puffing index. The need for mechanization of production of other flat breads is also high; hence, studies have to be focused on different processing parameters and its optimization for the mass production. This is the potential area to popularize and commercialize these Indian traditional flat breads across the globe.

**Table 6** Effect of additives on texture of fresh and stored *chapati*

| | | Fresh *chapati* (30 minutes) | | Stored *chapati* (24 hours) | |
|---|---|---|---|---|---|
| Sample | Water absorption (%) | Peak load to rupture (kN) | Modulus of deformation (Mpa) | Peak load to rupture (kN) | Modulus of deformation (Mpa) |
| Control | 57.0 | 0.0019 | 0.26 | 0.003 | 1.506 |
| Wet Gluten (g) | | | | | |
| 15 | 53.3 | 0.0024 | 0.293 | 0.0042 | 0.907 |
| 30 | 54.6 | 0.0022 | 0.178 | 0.0034 | 0.701 |
| 45 | 56.6 | 0.0021 | 0.125 | 0.0024 | 0.458 |
| Liquid Shortening (%) | | | | | |
| 2.5 | 52.0 | 0.0030 | 0.247 | 0.0038 | 1.796 |
| 5 | 51.3 | 0.0028 | 0.286 | 0.0037 | 1.276 |
| 7.5 | 50.0 | 0.0024 | 0.304 | 0.0035 | 1.585 |
| 10 | 46.6 | 0.0020 | 0.254 | 0.0034 | 1.411 |
| Skim milk powder (%) | | | | | |
| 2.5 | 53.3 | 0.0011 | 0.236 | 0.0038 | 1.311 |
| 5 | 52.6 | 0.0026 | 0.422 | 0.0046 | 1.509 |
| 7.5 | 52.0 | 0.0027 | 0.396 | 0.0051 | 1.591 |
| 10 | 51.3 | 0.0034 | 0.410 | 0.0052 | 1.540 |
| Carboxymethyl cellulose (%) | | | | | |
| 0.5 | 59.0 | 0.0035 | 0.380 | 0.0029 | 1.356 |
| 1.0 | 63.3 | 0.0028 | 0.257 | 0.0038 | 0.995 |
| 1.5 | 64.8 | 0.0024 | 0.220 | 0.0027 | 0.696 |
| Glycerol monostearate (%) | | | | | |
| 0.25 | 58.0 | 0.0027 | 0.345 | 0.0051 | 1.399 |
| 0.5 | 58.6 | 0.0029 | 0.233 | 0.0040 | 1.272 |
| 1.0 | 59.3 | 0.0031 | 0.240 | 0.0036 | 1.372 |
| Sodium caseinate (%) | | | | | |
| 0.5 | 62.1 | 0.0028 | 0.255 | 0.0048 | 1.079 |
| 1.5 | 68.7 | 0.0027 | 0.246 | 0.0041 | 1.097 |
| 2.5 | 72.3 | 0.0024 | 0.202 | 0.0035 | 1.064 |
| Diastase (%) | | | | | |
| 0.15 | 57.2 | 0.0022 | 0.325 | 0.0030 | 0.860 |
| 0.375 | 57.6 | 0.0023 | 0.327 | 0.0031 | 0.978 |
| 0.75 | 58.6 | 0.0025 | 0.337 | 0.0035 | 1.587 |

*Source*: Gujral and Pathak (2002).

## Tandoori Roti

*Tandoori roti* and *parantha* are the other popular flat breads prepared using whole-wheat flour. At present about 15 to 20% of the wheat produced in India is used for the preparation of *tandoori roti* baked in a special kind of oven called Tandoor, consisting of earthen pot with refractory brick wall. *Parantha* is made by pan-frying atta dough sheet on a hotplate. It may be stuffed with vegetables, such as boiled potatoes, radishes or cauliflower, and/or paneer (South Asian cheese). The *tandoori roti* has on an average of 20 cm diameter and 4.5 mm thickness, with wide variation in the texture. Generally, *tandoori roti* made from atta had better texture and flavor as compared to those made from mill atta (Saxena and Haridas Rao, 1995). The rheological characteristics of dough, total protein and gluten proteins, and high-molecular weight subunits composition of some of the wheat varieties in relation to their *tandoori roti*-making quality were studied by Saxena and Haridas Rao (1995). The results revealed that the flours having protein content of about 100 g/kg, total glutenin content of about 50 g/kg, Glu-1 protein subunit, and quality score of 6 were found to produce good quality *tandoori roti.* This inferred that medium hard wheat was suitable for the preparation of *tandoori roti*. A study related to the carbohydrate profile of wheat varieties indicated that arabinoxylans play an important role in *tandoori roti*-making quality of wheat (Saxena et al., 2000).

To establish the relationships between the factors affecting the quality of *tandoori roti* such as dough consistency, salt level, mixing time, baking time and temperature, and the responses relevant to the quality (overall sensory score) by setting optimum processing conditions for obtaining good *tandoori roti*, a study was carried out using response surface methodology by Saxena and Haridas Rao (1996a, 1996b). The study found that a water content of 720 mL/kg flour (corresponding to farinograph dough consistency of 800 BU), salt content of 11 g/kg flour, a mixing time of 3.7 minutes, a baking time of 37 seconds, and a baking temperature of 425°C resulted in better quality *tandoori rotis*.

Saxena and Haridas Rao (1996a, 1996b) reported the effect on the quality characteristics of tandoori roti baked in an electrical oven, a gas tandoor and a hot plate. They found that the maximum extent of change in the characteristics of protein, and least changes in starch characteristics occurred in rotis baked in an earthen tandoor and of all the ovens, earthen tandoor yielded the best quality tandoori rotis (Fig. 2). The rotis baked on an

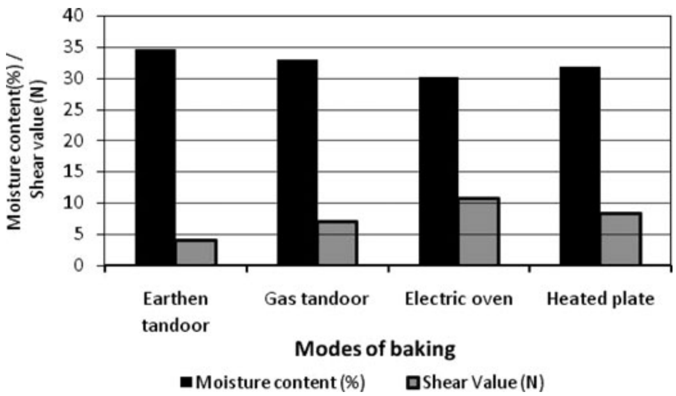


**Figure 2** Effect of different baking modes on moisture content (%) and shear value of *tandoori roti*. *Source*: Saxena and Haridas Rao (1996a, 1996b).

electrical oven was found to be acceptable and hence concluded that some modifications in the design of electrical oven can enable continuous production of good quality tandoori rotis.

## Puri

Next to *chapati* comes the *puri*, in terms of its consumption, which is a South Asian unleavened bread prepared in many of the countries in South Asia including India, Pakistan, and Bangladesh. It is consumed for breakfast, or as a snack or light meal. *Puri* is made from atta dough containing small quantity of table salt. The dough pieces are made into round balls and rolled into circles of varying diameters and deep-fat fried in edible oil. In some regions, maida (refined wheat flour), processed in roller flour mills, is also used for *puri* making; but unless consumed hot, its texture as well as eating quality are considered inferior to that of *puri* based on atta. As *puri* cannot be made from any cereal/pulse flours other than wheat, in many regions of the world, it is prepared from blends of imported wheat flour and locally grown maize (*Zea mays*), jowar (*Sorghum vulgare*) and Bengal gram (*Cicer arietinum*). A study was carried out by Shurpalekar and Shukla (1992) on the characteristics of *puri* dough and *puri* based on wheat flour (atta/maida) and possibilities of using composite flours based on wheat flour blends with other cereal/pulse flours for *puri* making. Incorporation of maize, Bengal gram, and jowar flours to atta at 10, 15, and 20% levels, respectively, yielded fully puffed *puris* with a very good rating. Texture of *puris* containing upto 20% of Bengal gram flour had better texture than those containing maize or jowar flour. *Puris* of good overall acceptability could be obtained from composite flours based on atta incorporated with maize/jowar flours at 15% level and Bengal gram flour at 20% level (Table 7). Sudha and Venkateshwara Rao (2009) reported the effect of hydroxylpropyl methylcellulose (HPMC) at various levels on the sensorial and instrumental evaluation of *puri*. Addition of HPMC in *puri* improved rheological characteristics of whole-wheat flour dough, pliability and eating quality and addition of 0.5% of HPMC increased oil uptake by about 0.5%. *Puris* were softer and pliable even after 8 hours of storage period. Scanning electron microscopic studies have shown HPMC coating the starch molecules.

**Table 7** Effect of composite flours on the quality and acceptability of *puri* made from atta

| | Puffing characteristics | | | Texture | | | |
|---|---|---|---|---|---|---|---|
| Flour% | [a]O | [a]S | Appearance | [b]O | [b]S | Eating quality | Overall acceptability |
| Atta | | | | | | | |
| 100 | 5.6 | Full | Very good | 5.12 | Soft | Very good | Highly acceptable |
| Maize | | | | | | | |
| 10 | 5.6 | Full | Very good | 6.43 | Soft | Very good | Highly acceptable |
| 15 | 5.1 | Full | Very good | 6.7 | Soft | Very good | Highly acceptable |
| 20 | 4.7 | Partial | Very good | 6.92 | Soft | Good | Acceptable |
| 25 | 4.1 | Partial | Good | 7.8 | Somewhat soft | Good | Not acceptable |
| 33 | 3.3 | No puffing | Fair | 8.16 | Somewhat soft | Fair | Not acceptable |
| Bengal gram | | | | | | | |
| 10 | 5.5 | Full | Very good | 5.13 | Soft | Very good | Highly acceptable |
| 15 | 5.4 | Full | Very good | 5.22 | Soft | Very good | Highly acceptable |
| 20 | 5.1 | Full | Very good | 5.43 | Soft | Very good | Highly acceptable |
| 25 | 4.3 | Partial | Very good | 5.61 | Somewhat soft | Good | Acceptable |
| 33 | 3.9 | No puffing | Good | 5.93 | Somewhat soft | Fair | Not acceptable |
| Jowar | | | | | | | |
| 10 | 5.1 | Full | Very good | 7.02 | Soft | Very good | Highly acceptable |
| 15 | 4.9 | Partial | Very good | 7.41 | Soft | Very good | Highly acceptable |
| 20 | 4.7 | Partial | Very good | 7.75 | Soft | Good | Acceptable |
| 25 | 3.8 | No puffing | Good | 8.25 | Somewhat soft | Good | Acceptable |
| 33 | 3.1 | No puffing | Fair | 9.2 | Slightly hard | Fair | Not acceptable |

[a]O: Objective evaluation of puffing characteristic (Puffing height, cm).
[a]S: Subjective evaluation of puffing.
[b]O: Objective evaluation of texture (WB shear value, lb).
[b]S: Subjective evaluation of texture.
*Source*: Shurpalekar and Shukla (1992).

### *Nutritive Value of Whole-Wheat Flour-Based Products*

The nutritive value of *chapati* depends entirely on the chemical composition of the wheat as only whole-wheat flour and water are used for its preparation, whereas *puri* and *parantha* has the effect of other ingredients on its nutritive value. During preparation of *chapati*, vitamin B and lysine decreased (Mehdi and Abrol, 1972). The phytic acid present decreased the bioavailability of several mineral elements (O'Dell et al., 1972; Bassiri and Nahapetian, 1977; Honig et al., 1984). *Chapati*, being a whole-wheat flour product, has higher Zn availability (Grewal et al., 1999). The effect of simultaneous removal of fines (0–40%) and bran (0–10%) led to an increased tendency of using highly refined flour containing lower concentration of mineral elements (Sabir et al., 1982). The combination of simultaneous removal of 5% bran and 10% fines was found to be the best for good quality *chapaties*. Inclusion of sodium chloride, Bengal gram flour, and desi ghee, which is an excellent source of fat-soluble vitamins, improved the *chapati* quality (Balmeer Singh et al., 2005). As cereals are deficient in the lysine content, the lysine-rich ingredients can be added to *chapati*. Incorporation of soy, peanut, and cottonseed flours increased the protein content of *chapaties.* Soy, peanut, and cotton seed flour incorporation at 10 and 20% level increased the available lysine content of *chapaties* by 73 and 146, 27 and 58, and 48 and 87%, respectively (Bhat and Vivian, 1980). Some of the weaning food formulae were experimented with *chapati* along with the incorporation of green gram, and Bengal gram flour was found to be cost effective with enriched nutrition (Malleshi et al., 1986). Concentration of minerals namely P, Zn, Fe, Mn, and Ca and protein efficiency ratio increased in *chapaties* supplemented with either chickpea or pigeon pea flour (Sharma et al., 1995). In a study conducted to know the nutritionally important starch fractions in cereal-based Indian food preparations, it was found that, the fat content of *Puri* was the highest (24%), whereas protein content ranged between 11 and 13% (Sharavathy et al., 2001). The total starch content in *puri* (on dry basis) was around 40.5%. Also, addition of accompaniment showed no effect on the total starch content of *puri.* Slowly digestible starch (SDS) content of 14 to 19 g and rapidly available glucose (RAG) content of 6.7 g/100 g were found in *puri* and addition of an accompaniment decreased the starch digestion index (SDI). The nutrients (Zn, Ca, and Fe) availability from *puri* was found to be less when compared to *chapaties* (Grewal et al., 1999). With the aim of increasing the nutritive value of *puri,* many of the supplementations are generally followed and effect on the nutrient availability was studied. It was found that the *puris* can be prepared by incorporation of amaranth (*Amaranthus tricolor*) leaves to increase the Ca, Fe, and $\beta$-carotene availability in the daily diet (Darshan et al., 2004). Grewal et al. (1999) have analyzed the availability of some of the minerals in *parantha*. It was found that the phytic phosphorus contents of *parantha* differed significantly from other Indian flat breads. In an experiment conducted on rats fed with *chapati* and *parantha* made out of whole-wheat flour and pearled wheat flour, higher Zn absorption/retention was found in *chapaties* compared to *parantha* diets (Grewal and Hira, 2003). To enhance the vitamin A content, *parantha* was prepared out of deacidified and deodorized palm oil, a rich source of $\beta$-carotene. The organoleptic tests of these *parantha* were carried out and were found to be highly acceptable and hence suggested for combating vitamin A deficiency (Kapil et al., 2001). The amino acid composition, true digestibility (TD) of protein, biological value (BV) of protein, and net protein utilization are the parameters indicative of protein quality of a product. Lysine and tryptophan which are the limiting amino acids in most of the cereal-based products are present in traditional whole-wheat based flat breads in the range of 2.22 to 2.49 g/16 g N and 1.01 to 1.18 g/16 g N, respectively. The TD of *puri* is the highest with 98.1%, followed by *chapati* (95.9%), *parantha* (93.6%), and *tandoori roti* (92.1%). BV is a measure of the proportion of absorbed protein from a food which becomes incorporated into the proteins of the organism's body. It summarizes how readily the broken down protein can be used in protein synthesis in the cells of the organism. A ratio of nitrogen incorporated into the body over nitrogen absorbed gives a measure of protein BV. *Tandoori roti* had highest BV of 60.4%, followed by *parantha* (58.7%), *puri* (58%), and *chapati* (57.5%). The net protein utilization (NPU) is the ratio of amino acid converted to proteins to the ratio of amino acids supplied. Puri has the highest NPU value of 56.9%, followed by on par values of *tandoori roti* and *chapati* (55%) and *parantha* with a value of 54.9%.

## *REFINED WHEAT FLOUR-BASED FLAT BREADS*

The refined flour obtained from roller flour mill is used as a main ingredient in the preparation of many of the traditional products such as South Indian *parotta*, *naan, bhatura*, *kulcha* etc.

### South Indian Parotta

*South Indian parotta* is a multilayered, circular shaped, creamish white colored flat bread made from refined wheat flour (maida). It is one of the staple food items of the southern states of India, also called Kerala *parotta*, Ceylon *parotta*, or simply *parotta*. Over the last 50 years, the predominantly rice-eating population of South India has increased its per capita consumption of wheat substantially, mainly in the form of traditional foods like *chapaties*, *phulka*, South Indian *parotta*, *naan*, and *bhatura* (Indrani, 1998). More than 50% of wheat flour produced by the roller flour mills in South India is utilized for their preparation.

#### *Factors Influencing the Quality Characteristics of* Parotta

*Parotta* is prepared using wheat flour as the main raw material along with salt, sugar, water, and oil (Indrani and Venkateswara

Rao, 2001). *Parotta* dough is sheeted to form a thin film with the help of refined oil, folded into multiple layers and then coiled. The coiled dough is sheeted into a circular disc and baked. The baked product possesses light brown spots on the surface, a soft pliable handfeel, soft and slightly chewy texture, with distinct layers, optimum oiliness, easy breakdown in the mouth, and typical pleasant taste and aroma (Indrani et al., 2000).

The chemical and rheological characteristics influencing the quality of *parotta* have been identified (Indrani and Venkateswara Rao, 2000). Among the chemical characteristics, quantity and quality of protein was found to be the best index in predicting the quality of *parotta*. Dry gluten content showed greatest correlation with color ($r = 0.99$, $p \leq 0.001$), while nature of spots was correlated with damaged starch ($r = 0.99$, $p \leq 0.001$). The flour protein content showed highest correlation coefficient with sensory scores, indicating that the protein content was the major factor influencing the quality of *parotta*. Rheological characteristics such as farinograph water absorption, extensograph ratio figure, extensograph area and ABEV (Apparent biaxial extensional viscosity), hardness, and cohesiveness were found to be highly correlated to overall quality score of *parotta*. Sensory texture of *parotta* was found to be highly correlated to shear and compression forces, indicating that shear and compression force could be considered as the best indices of sensory texture of *parotta*. Effect of processing conditions on the quality characteristics of *parotta* has been studied (Indrani and Venkateswara Rao, 2004). With decrease or increase in mixing time from four to one or four to eight minutes, the diameter/thickness (D/T) ratio of *parottas* decreased from 29.4 to 27.9 and increased from 27.9 to 32.3, respectively. The *parottas* made by mixing the dough for a short period of one minute, or for a long period of eight minutes, had dull color. The shear force value decreased from 15.7 to 11.8 N with increase in rest period from 0 to 60 minutes, whereas it increased from 11.6 to 14.1 N with increase in thickness from 2.5 to 7.5 mm. The shear force value decreased with decrease in baking time from two to one minute as well as with decrease in baking temperature from 230 to 175°C, whereas it increased with increase in baking time from two to three minutes. The optimum processing conditions such as mixing time, 4.0 minutes; rest period, 30 minutes; sheeting thickness, 5.0 mm; baking time, 2.0 minutes, and baking temperature, 230°C have been arrived at, to carry out test baking experiments on *parotta* in a lab scale under controlled conditions. Ingredient optimization for a better quality *parotta* was done using response surface methodology (RSM). The response surfaces and contour maps showing the interactions of the ingredients indicated that an improved *parotta* quality could be achieved by decreasing the water content, increasing the oil content, and keeping the salt, sugar, and egg concentration within a narrow range of variation from the middle levels of water (60.0), oil (10.0), salt (1.0), sugar (1.0), and egg (15.0) (Indrani and Venkateshwara Rao, 2001). SEM and electrophoresis have proved to be valuable tools for observing the molecular interactions of major components of wheat flour during the baking process of *parotta* (Prabhasankar et al., 2003).

### *Effect of Additives*

The rheological characteristics of wheat flour dough and quality of *parotta* as influenced by the use of various oxidizing agents, reducing agents, gluten and enzymes and the identification of the additives to improve the quality characteristics of flour for *parotta* (Table 8) making were studied by Indrani and Venkateshwara Rao (2006). The rheological modifications brought about by 100 ppm of potassium metabisulphite, 50 ppm of cysteine hydrochloride, or 10 ppm of protease resulted in producing *parotta* of highly desirable quality. Same results were obtained with regard to the effect of enzymes on *parotta* quality. The *parotta*-making quality was improved by all the surfactants tested; however, the highest improvement in the overall quality of *parotta* was brought about by sodium stearoyl lactate (SSL) and polyoxyethylene sorbitan monostearate (PS-60) at a 0.5% flour weight basis (Indrani and Venkateshwara Rao, 2003). Among the different enzymes such as fungal amylase, glucose oxidase, proteinase, and xylanase, rheological characteristics of the dough and overall quality of *parotta* improved on usage of proteinase and xylanase, which was evident from the micrographs of *parotta* dough and product (Prabhasankar et al., 2004). Addition of hydrocolloids increased the water absorption capacity of dough. The strength and elasticity of the dough increased with Xanthan gum (XG). The elasticity of the dough was moderately increased by Gum Arabic (GA), guar gum (GR), carrageenan (CG), and HPMC. Dough was more extensible with GA and HPMC. The peak viscosity was highest with GR and setback was lowest with XG. Microstructural characteristics of dough with hydrocolloids showed that the starch granules were coated with gum. The coating was more evident in the case of dough with GG and HPMC (Smitha et al., 2008).

### *Storage Stability of* Parotta

There is a considerable potential for the large-scale manufacture and marketing of *parotta*, as the demand for ready-to-eat convenience food products have been steadily increasing because of industrialization. It calls for mechanization in the preparation and distribution in unit packs. For achieving the objective of commercial marketing, it is desirable that the *parotta* should have adequate shelf-life. For extending the shelf-life of any product, knowledge regarding the changes taking place in the product during storage is necessary. A study carried out showed that there was a decrease in the quality characteristics of *parotta* such as, alkaline water retention capacity (AWRC), total water soluble (TWS), soluble starch (SS), amylase, amylopectin, viscosity, and overall quality score with increase in storage time (Indrani et al., 2000). The overall quality showed highly significant correlation with SS, amylopectin, and rapid viscosity analyzer (RVA) at 95°C after 15 minutes. Changes in rheological and protein characteristics of frozen *parotta* dough (FPD) and

**Table 8** Effect of additives on rheological characteristics of wheat flour dough

| | Compressive stress (N/cm$^2$) | Hardness (N) | Cohesiveness | Adhesiveness (N.s) |
|---|---|---|---|---|
| Control | 0.35 | 36.45 | 0.782 | 26.55 |
| Potassium bromate | | | | |
| 20 ppm | 0.35 | 36.85 | 0.788 | 26.41 |
| 40 ppm | 0.37 | 39.89 | 0.794 | 25.83 |
| Potassium iodate | | | | |
| 20 ppm | 0.54 | 47.52 | 0.844 | 24.31 |
| 40 ppm | 0.70 | 49.34 | 0.865 | 22.10 |
| Ascorbic acid | | | | |
| 100 ppm | 0.39 | 40.52 | 0.821 | 25.21 |
| 200 ppm | 0.41 | 44.32 | 0.842 | 24.12 |
| Potassium metabisulfite | | | | |
| 100 ppm | 0.199 | 28.11 | 0.632 | 28.53 |
| 200 ppm | 0.167 | 26.55 | 0.601 | 30.52 |
| Cysteine hydrochloride | | | | |
| 50 ppm | 0.30 | 29.55 | 0.651 | 28.05 |
| 100 ppm | 0.23 | 27.14 | 0.612 | 30.12 |
| Glycerol monostearate (GMS) | | | | |
| 0.5% | 0.286 | 30.1 | 0.790 | 26.10 |
| Lecithin | | | | |
| 0.5% | 0.270 | 29.6 | 0.796 | 25.31 |
| Sodium stearoyl lactylate | | | | |
| 0.5% | 0.338 | 32.8 | 0.832 | 23.12 |
| Diacetyl tartaric acid esters of mono glyceride (DATEM) | | | | |
| 0.5% | 0.318 | 30.8 | 0.801 | 24.21 |
| Poly sorbate-60 (PS-60) | | | | |
| 0.5% | 0.326 | 30.5 | 0.828 | 23.12 |

*Source*: Indrani and Venkateswara Rao, (2003); Indrani and Venkateswara Rao, (2006).



*parotta*-making characteristics of ready-to-bake frozen *parotta* dough (R-FPD) during storage and the effect of thawing conditions on the quality of *parotta* were studied by Indrani et al. (2002). It was observed that the *parotta* dough even after storage for three months at −20°C retained rheological and *parotta*-making characteristics (Fig. 3). The quality of the product prepared from frozen dough was not affected significantly. The optimum thawing conditions of frozen *parotta* was found to be one minute in a microwave oven or 16 hours at 4°C in a refrigerator.

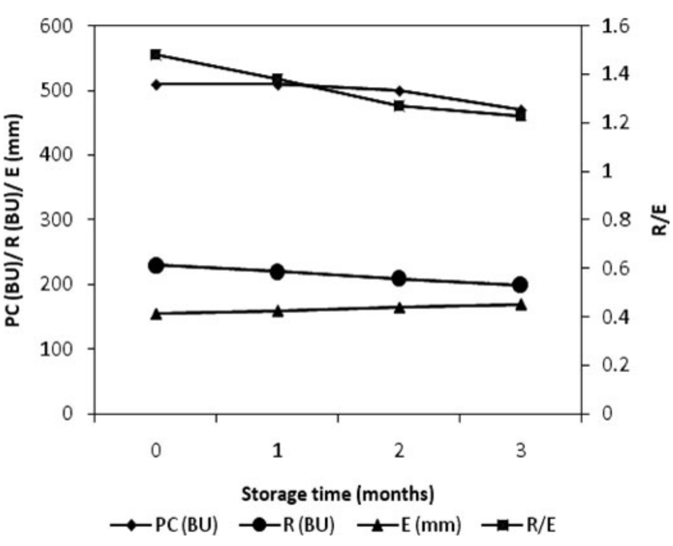


**Figure 3** Effect of storage on farinographic and extensographic characteristics of stored frozen *parotta* dough (FPD). PC, peak consistency; R, resistance to extension; E, extensibility; R/E, ratio figure. *Source*: Indrani et al. (2002).

### *Other Flat Breads from Refined Wheat Flour*—Naan/bhatura/kulcha

*Naan,* a popular traditional food of the Indian subcontinent is a flat leavened bread made from *maida* (refined wheat flour). It is relatively more nutritious than *chapati and roti*, as it is prepared from fermented dough containing milk, curd (yoghurt), and egg. Besides the main ingredient *maida*, other ingredients used invariably are vanaspati (hydrogenated oil)/oil, salt, curd, and baking soda. Egg, sugar, and milk are also used often. *Naan* should be soft to touch, spongy to handfeel, somewhat firm to tear, a little chewy to bite without sticking to teeth and possess a characteristic fermented flavor and a good overall acceptability. In India, *naan* is made from straight run flour of about 72% extraction, whereas in Pakistan it is made from brown flours with extraction rates in the range of 88%. The straight run flour and brown flour used for *naan* preparation would typically have the characteristics listed in Table 9. *Bhatura* is soft and fluffy Indian deep fried bread, and is often eaten with a chickpea curry, *chole*, making the classic Punjabi dish *chole bhature*. A typical recipe includes refined wheat flour (*maida*), yoghurt, ghee or oil, and yeast. The lactic acid in the yoghurt reacts with baking soda to make dough light and rise (six hours). Once kneaded

**Table 9** Characteristics of typical flour for *naan* production

| Characteristics | Straight run flour | Brown flour |
|---|---|---|
| Extraction (%) | 72 | 88 |
| Particle size* | 18.6–22.7 | – |
| Moisture (%) | 13.9 | 13.1 |
| Ash (%) | 0.53 | 0.92 |
| Wet gluten (%) | 32.1 | 25.3 |
| Protein (%) | 11.0 | 10.6 |
| Farinograph Water absorption (%) | 62.5 | 63.0 |
| Dough development time (min) | 10.5 | 3.5 |
| Stability (min) | 2.5 | 6.0 |
| Breakdown (BU) | 20 | 80 |
| Valorimeter value | 80 | 48 |
| Extensograph data: | | |
| Extensibility (cm) | 16 | 16 |
| Max. Resistance | 630 | 220 |
| Energy | 140 | 49 |

*Source*: Hashmi and Wootton, (1995); Rahim et al. (1993).

well, the dough is left to rise, and then small balls of it are either hand rolled or flattened using a rolling pin. Then it is deep fried (350°F for about 40 seconds) until they puff up into light brown soft fluffy bread, which is elastic and chewy. *Kulcha* is typical North Indian leavened bread prepared with refined wheat flour. Flour dough, mashed potatoes, onion and lots of spices are rolled into a flat round bread and baked in an earthen clay oven until golden brown. When baked, it is smeared with butter and then eaten with spicy *chole* (curry). Dough is prepared by adding salt, sugar, oil, curds, and yeast to flour and mixed using hot water. Kneaded dough is covered by a damp cloth and incubated in a warm place for 2 hours. Then the ball of dough is rolled into flat circular *kulchas* and baked on a pan with small quantity of butter/oil applied on its surface.

There are fewer reports related to *naan*. Rahim et al. (1993) developed a laboratory method of *naan* preparation. Based on the results, the optimum levels of ingredients and the desired processing conditions were arrived for the preparation of dough of desired consistency and *naan* of good quality. In order to improve the nutritional quality of *naan*, *bhatura*, and *kulcha*, a study was conducted by Dogra et al. (2001). They studied the acceptability of *naan*, *bhatura*, and *kulcha* incorporated with soaked and germinated (48 and 96 hours), heated (80°C for 15 minutes) and roasted (20 minutes) soybeans that were analyzed. It was found that the scores for color, taste, and texture of *naan* decreased upon addition of soy flour but the same improved on addition of soaked and germinated ones. Addition of soy flour increased the water absorption in *bhatura*. The puffing in *bhatura* was full in case of those prepared from wheat flour (100%) as well as those from wheat flour containing 20% soy flour. With regard to organoleptic properties, addition of soaked and germinated soy flour improved the color, taste, and overall acceptability of *bhatura*. Supplementation upto 30% levels yielded improved quality *bhatura*. Supplementation of refined wheat flour with soybean flours upto 15% levels was found to be acceptable.

## FUTURE PROSPECTS OF WHEAT-BASED FLAT BREADS

With the changing life style, urbanization, modernization, and globalization, the demand for ready to eat (RTE) or ready to prepare foods are increasing. The traditional flat breads have become popular even in the areas where, traditionally, rice has been the staple diet. Further studies related to use of nonwheat cereals to improve the nutritional profile of the flat breads are to be carried out. Increasing demand for these products calls for mechanization of production to produce ready-to-eat and easy to carry food along with assuring the quality, nutrition, and safety of the products. To cater to these needs, sound scientific studies that throw light on different properties of these products have to be systematically planned to obtain necessary details that would help in the realization of large-scale production through mechanization. Extension of shelf-life could be achieved by employing different treatments, by adding preservatives additives, and by using improved packaging that would facilitate long-term storage and safety of the products. Improving nutritional properties of the products could be explored by supplementation etc.

A good quantum of research work has been done with regard to the products such as *chapati* and South Indian *parotta* which has led to the development of shelf-stable *chapati*, frozen *parotta* dough, frozen *parotta* etc. But, on the other hand, the studies and research reports regarding other flat breads such as *puri*, *tandoori roti*, *parantha*, *kulcha*, *bhatura*, *naan* etc. are scanty. There is a need to divert the interest of the scientific community toward these products to know their properties and functionalities that would pave way for the development of shelf-stable, convenient, nutritious food products which would be one of the major ways of combating malnutrition and help to ensure food security across the globe.

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