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Technical paper

Effects of Hydrocolloids on Partial Baking and Frozen Storage of Wheat Flour Chapatti

Anwaar Ahmed[1], Mahwish Anjum[1], Asif Ahmad[1], Nauman Khalid[4*], Muhammad Atif Randhawa[2], Zulfiqar Ahmad[3] and Wajiha Farid[1]

[1] *Department of Food Technology, PMAS-Arid Agriculture University, Rawalpindi, 46300, Pakistan*
[2] *National Institute of Food Science & Technology, University of Agriculture, Faisalabad, 38040, Pakistan*
[3] *University College of Agriculture and Environmental Sciences, The Islamia University of Bahawalpure, Bahawalpure Pakistan*
[4] *Graduate School of Agricultural and Life Sciences, University of Tokyo, 1-1-1 Yayoi, Bunkyo-ku, Tokyo, 113-8657, Japan*

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The use of hydrocolloids in different foods systems has become more commonly applied to improve the texture and quality of baked products. Nevertheless, the effects of these compounds on partially baked frozen chapatti have not been studied. The objective of the present study was to improve the storage stability, quality and shelf life of partially baked chapatti by adding various hydrocolloids, hydroxyl propyl methylcellulose (HPMC), carboxy methylcellulose (CMC) and guar gum, followed by frozen storage for 28 days. Partially baked and fully baked chapattis after frozen storage were analyzed for chemical and sensory attributes at 7-day intervals. Rheological studies showed an increase in water absorption, dough development time and dough stability after the addition of hydrocolloids. In partially baked chapatti with hydrocolloids after frozen storage, an increase in moisture retention and water soluble starch was observed. Sensory characteristics were also improved by combining both techniques. Among the hydrocolloids, HPMC exhibited the best results, followed by CMC and guar gum. These hydrocolloids and partial baking with frozen storage helped to improve the quality, and extend the shelf life of partially baked chapatti.

Keywords: partially baked chapatti, frozen storage, hydrocolloids, HPMC, CMC, guar gum

Introduction

Wheat constitutes approximately 80 percent of the total cereal intake in Pakistan (Hussain *et al.*, 2004). About 90 percent of this is used for production of chapatti (Siddqiui, 1989), which is the main staple food of the Pakistani people and principal source of energy and protein (Hussain *et al.*, 2004), contributing about 72 percent of total calories to their daily diet (Zahoor *et al.*, 2004).

However, chapatti becomes stale a few hours after baking, deteriorating in quality and increasing in firmness, rigidity and chewiness (Gujral and Pathak, 2002; Asghar *et al.*, 2006). During cooking, starch in the wheat flour gelatinizes, and its behavior on cooling and storage is termed as staling, which affects eating quality, acceptability and shelf life (Biliaderis, 1991).

Several studies have been conducted to overcome, or at least minimize or delay the staling of chapatti. The most efficient and applicable methods are partial baking (Fik and Surowka, 2002), freezing or frozen storage (Matuda *et al.*, 2005), and addition of anti-stalling agents (Kohajdova *et al.*, 2009), enzymes (Haros *et al.*, 2002) or yeast (Skotnicka and Palich, 2008) to retard the staling of chapatti.

Freezing of partially baked chapatti (Labutina *et al.*, 1981) significantly decreases the microbial, enzymatic and chemical activity during storage (Morgenstern, 1985), but thawing has deleterious effects on texture, which can be recovered by the use of antistaling agents, emulsifiers, surfactants (complexing agents), enzymes (e.g. α-amylase), gums and hydrocolloids (Barcenas *et al.*, 2003). Use of hydrocolloids is particularly important for improving the stability and shelf life of partially baked frozen chapatti (Gurkin, 2002),

*To whom correspondence should be addressed.
E-mail: nauman_khalid120@yahoo.com

as it decreases the negative effects of freezing on starch retrogradation (Ferrero *et al.*, 1993; Liehr and Kulicke, 1996).

Hydrocolloids are hydrophilic in nature, and thus help to avoid the ice crystal formation and water migration under frozen conditions, improving freeze-thaw stability (Fiszman and Salvador, 2003), water absorption, and dough rheological (Mandala *et al.*, 2007) and pasting properties (Gomez *et al.*, 2007). Because of their neutral taste and aroma, they do not impart flavor of the final product (Kohajdova *et al.*, 2009).

Various hydrocolloids, including hydroxypropylmethylcellulose (HPMC), carboxymethylcellulose (CMC) (Chinachoti, 2005), guar gum, diacetyl-tartaric acid ester of monoglycerides (Ribotta *et al.*, 2003), k-carrageenan, Arabica gum (Sharadanant and Khan, 2003a) and alginates have been added to bread in order to improve its rheological properties, pliability and shelf life.

As chapatti is the staple food of Pakistan and India, its shelf life and eating quality must be improved. The main objective of this study was to therefore to extend the shelf life of partially baked chapatti by adding different hydrocolloids prior to frozen storage.

Materials and Methods

Procurement of Raw Materials Wheat flour of commercial grade was purchased from Sehala Flour Mills (Rawalpindi, Pakistan). The flour had a protein and ash content of 12.1% and 1.51% respectively. The detailed composition of wheat flour is shown in Table 1. Various food-grade hydrocolloids, such as HPMC, CMC, guar gum and sodium propionate, were manufactured by Sigma Corporation and were supplied by Standard Scientific Store (Rawalpindi, Pakistan). Chapatti was prepared by incorporation of hydrocolloids (0.5% HPMC, CMC and guar gum) into whole wheat flour. Sodium propionate (0.3%) was added for all the treatments; T_0 refers to control with no hydrocolloids, T_1 contains HPMC, T_2 contains CMC and T_3 contains guar gum.

Baking of chapatti Chapatti was baked according to the method described by Gujral *et al.* (2008). Chapatti dough was prepared by mixing whole wheat flour (150 g) and water was added based on the Farinographic water absorption. About 45 g of dough was rounded and placed on a rolling board, and spread to a diameter of 150 mm using a rolling pin. This gave dough of about 2 mm in thickness. The dough was first rolled in one direction, inverted and then rolled in the perpendicular direction.

Table 1. Chemical composition of wheat flour

Constituents	Percentage ± S.D.
Moisture content	13.13 ± 0.2
Crude protein	12.10 ± 0.2
Crude fat	1.94 ± 0.1
Ash content	1.51 ± 0.1
Wet Gluten	23.27 ± 0.3
Dry Gluten	10.17 ± 0.2

*All values are means of three analyses

Partially baked chapatti The sheeted dough was placed on a hot plate (250°C) and baked for 15 sec on one side and 10 sec on other side. Preservation of partially baked chapatti was performed in batches, followed by storage at −18°C for a period of 4 weeks in specially designed aluminum boxes, special care was taken to exclude as much air as possible in order to avoid damage and to maintain chapatti structure.

From the freezer, the frozen partially baked chapatti samples were collected at 7-day intervals, and were allowed to thaw for 2 h, with re-baking for 15 s on one side and 10 s on other side, followed by cooling for 10 min at 25°C. The freezing and thawing conditions were set based on a previous study conducted by Gujral *et al.* (2008). Chapattis were rebaked to completion and sensory evaluation was then carried out.

Chemical and Rheological study Chemical analysis of wheat flour and chapatti were conducted as described by AACC (2000), including moisture by method No.44-15, crude protein by method No.46-10, crude fat by method No.30-10, ash by method No. 08-01, and dry and wet gluten content by method No.38-10. Rheological studies, including water absorption, dough development time and dough stability were conducted according to AACC (2000) method No. 54-21. Water soluble starch was determined by a modified procedure of Morad and D'Applonia (1980). Rheological analysis was conducted at the National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan.

Sensory Evaluation of Chapatti Chapattis were evaluated on the Hedonic scale for sensory parameters such as color, taste, aroma, texture, chewability, foldabilty and overall acceptability by a trained panel of judges according to the method described by Larmond (1977). Chapattis were brought to the sensory analysis lab, after cooling for 15 min at room temperature, and were served to the panelists. Judges were provided with prescribed questionnaires to record their observations. The sensory scale was: 9 = like extremely; 8 = like very much; 7 = like moderately; 6 = like slightly; 5 = neither like nor dislike; 4 = dislike slightly; 3 = dislike moderately; 2 = dislike very much; and 1 = dislike extremely. Sensory testing was performed in a panel room completely free of food/chemical odors, unnecessary sounds and mixing of daylight.

Statistical analysis Data obtained for each parameter was analyzed statistically in order to assess the changes in various parameters, as described by Steel *et al.* (1997). Means were compared with Duncan's Multiple Range test (DMRt) using a Statistical Package (Minitab, Version 11.0). Significance was set at $p \leq 0.05$. Each experiment was repeated at least twice and the values are reported as means.

Results and Discussion

The results for moisture, ash, protein, fat and gluten content are presented in Table 1. The results showed that the whole wheat flour contained 13.13% moisture, 12.1% crude protein, 1.94% crude fat, 1.51% ash, 23.27% dry gluten and 10.17% wet gluten. The results for the moisture are within the limits established by Barcenas and Rosell (2006). The results for ash were closer to those of Siddqiui (1989), while crude fat, and wet and dry gluten were in conformity with the findings of Shaikh *et al.* (2007).

Effects of hydrocolloids on dough rheology The results of dough rheology are shown in Table 2. It is clear from the results that the water absorption of flour increased with the incorporation of hydrocolloids (HPMC and CMC) into wheat flour. The highest water absorption was 69.8 ± 0.7% in T_1, which contained 0.5% HPMC, followed by CMC. Significantly lower (68.4 ± 0.4%) water absorption was observed in wheat flour containing 0.5% guar gum.

The HPMC-added dough showed the highest water absorption, followed by CMC. These results corresponded to those of Sahalini and Laxmi (2007), who reported an increase in water absorption with the addition of HPMC and CMC, as the high number of hydroxyl groups allow more hydrogen bonding to hold water. Similarly, in another study, it was reported that HPMC increases water retention capacity (Rosell and Foegeding, 2007; Khan *et al.*, 2011).

The mean values for dough development time in the different flour samples are shown in Table 2. The dough development time varied from 3 min to 4.5 min among the different treatments. Significantly higher dough development time (4.5 min) was observed in T_1 (0.5% HPMC), with non-significant differences observed for T_2 (0.5% CMC) and T_3 (guar gum), while T_0 (control sample) showed significantly lower dough development time (3 min). These results supported the findings of Rosell *et al.* (2001).

The mean values showing the effects of different hydrocolloids on the dough stability of wheat flour are given in Table 2. The mean values for dough stability ranged from 5 to 7 min. The results suggest that addition of hydrocolloids increased dough stability, as compared to control samples. The highest dough stability was found to be 7 min in T_2 (0.5% CMC), with non-significant differences for T_1 (HPMC) and T_3 (guar gum), while the lowest dough stability was seen in the control sample. Thus, the dough containing CMC had the highest stability, followed by HPMC and guar gum, which agrees with the the findings of Sharadanant and Khan (2003a; 2003b).

Effects of hydrocolloids on chemical composition of fully baked chapatti after partial baking and frozen storage Mean values for the effects of different treatments on the chemical composition of partially baked chapattis are given in Table 3, and the effects of storage interval on chemical composition with HPMC are given in Table 4. The results confirm that the moisture contents of partially baked

Table 2. Means values showing effects of different hydrocolloids on dough rheology

Treatments	Water absorption (%)	Dough development time (min)	Dough stability (min)
T_0	68.4 ± 0.5c	3.0 ± 0.1b	5.0 ± 0.2c
T_1	69.8 ± 0.7a	4.5 ± 0.2 a	5.5 ± 0.1b
T_2	69.6 ± 0.6b	4.0 ± 0.2a	7.0 ± 0.3a
T_3	68.4 ± 0.4c	4.5 ± 0.1a	5.5 ± 0.3b

Means with common letter in a column are not significantly different at the 5% probability level

Table 3. Effects of hydrocolloids on chemical composition of partially baked chapattis after frozen storage

Treatments	Moisture Content (%)	Crude protein (%)	Crude fat (%)	Ash (%)	Water soluble starch (%)
T_0	30.29 ± 0.2d	11.68 ± 0.1a	1.69 ± 0.1a	1.50 ± 0.1a	4.45 ± 0.2b
T_1	32.15 ± 0.3a	11.74 ± 0.2a	1.74 ± 0.1b	1.49 ± 0.2a	4.56 ± 0.3a
T_2	31.50 ± 0.2b	11.71 ± 0.4a	1.66 ± 0.1c	1.49 ± 0.1a	4.50 ± 0.2 ab
T_3	31.04 ± 0.2c	11.66 ± 0.3a	1.70 ± 0.1a	1.49 ± 0.1a	4.52 ± 0.1ab

All values are means of three experiments
Means carrying same letters are not significantly different at alpha = 0.05

Table 4. Effects of storage on chemical composition of partially baked chapatti containing HPMC after frozen storage

Parameters	Moisture content (%)	Crude protein (%)	Crude fat (%)	Ash (%)	Water soluble starch (%)
Fresh	32.15 ± 0.4a	12.08 ± 0.2a	1.98 ± 0.3a	1.51 ± 0.1a	5.29 ± 0.2a
7th day	31.33 ± 0.3ab	11.92 ± 0.4b	1.84 ± 0.2b	1.50 ± 0.2a	4.92 ± 0.3b
14th day	31.45 ± 0.2c	11.69 ± 0.3c	1.70 ± 0.1c	1.50 ± 0.3a	4.53 ± 0.3c
21st day	31.59 ± 0.5ab	11.49 ± 0.4d	1.55 ± 0.2d	1.49 ± 0.2 a	4.10 ± 0.2d
28th day	32.13 ± 0.5a	11.31 ± 0.2e	1.43 ± 0.1e	1.49 ± 0.1a	3.69 ± 0.3e

Means with common letter in a column are not significantly different at the 5% probability level

chapatti range from 30.29% to 32.15% among the different treatments after 28 days. The highest moisture content was found to be 32.15% in T_1 (HPMC), with non-significant differences for T_2 (CMC) and T_3, and the lowest moisture content was 30.29% in the control sample. The increase in moisture content may be due to the water holding capacity of hydrocolloids. Similar findings were obtained by Barcenas *et al.* (2003), who reported an increase in moisture content of bread with addition of HPMC, while other studies showed an increase in moisture content of bread by addition of CMC (Khan *et al.*, 2011; Abu-Ghoush *et al.*, 2002).

It is also clear from the results (Table 4) that during frozen storage, moisture content significantly decreased up to 14 days, then abruptly increased up to 28 days of frozen storage in the case of HPMC. These results are strongly in accordance with the findings of Barcenas and Rosell, (2006) who reported decreases in the moisture contents of frozen partially baked bread (at −25°C) for up to 14 days, followed by an increase in moisture content up to 42 days of storage. During storage, the highest moisture content (32.15%) was observed at day 0 (fresh) for partially baked chapatti, but the difference at day 28 was not significant.

In the present study, while comparing the effects of different hydrocolloids on moisture retention in chapatti, addition of HPMC exhibited highest moisture content, followed by CMC and guar gum.

Table 4 shows that differences in storage interval significantly ($p < 0.05$) affect the protein contents of chapatti during storage, whereas, non-significant differences in storage intervals were seen for ash content. It is evident from the mean values for protein content that there was significant decrease in crude protein during frozen storage of partially baked chapatti containing HPMC. At day 0 (fresh), protein was 12.08%, and this decreased significantly to 11.92% on day 7, 11.69% on day 14, 11.49% on day 21, and 11.31% on day 28. In the present investigation, decreases in the protein content of partially baked chapatti were attributed to the protease activity that is responsible for protein degradation during storage, while the results for crude protein and ash content were found to be non-significant among the different treatments. Proteolytic activity of these enzymes may have been elevated by the high moisture contents or may have been due to the presence of enzyme-rich constituents of wheat grains, for example bran and the aleurone layer (Leelavathi *et al.*, 1984). Storage had no significant effect on ash content. These results corresponded to those by Anjum *et al.* (2003), who reported no significant effects for storage on ash contents

Partially baked chapatti in the T_0 (control) and T_3 (guar gum) groups had highest contents of crude fat, followed by chapatti containing HPMC. The lowest value for crude fat was seen in samples containing CMC. The difference in storage intervals significantly ($p < 0.05$) affected the crude fat contents of chapatti containing HPMC (Table 4). On day 0 (fresh) the mean fat content was 1.98%, and this decreased significantly to 1.84% on day 7, 1.70% on day 14, 1.55% on day 21, and 1.43% on day 28. During storage, the decrease in fat content is due to the development of rancidity (Leelavathi *et al.*, 1984), as a result of the activation of lipase and lipoxidase enzymes, which split fat into fatty acid and glycerol, and high moisture during storage may accelerate this reaction (Kent and Evers, 1994). Lipolysis accelerates the release of free fatty acids, and these acids oxidize by absorbing oxygen, leading to rancidity (Staudt and Zeigler, 1973).

The partially baked chapattis containing HPMC had highest contents of water soluble starch, followed by those containing guar gum and CMC. T_0 (control) had lowest content of water soluble starch. Storage decreased water soluble starch levels in chapatti, and differences in storage intervals significantly ($p < 0.05$) affected the water soluble starch contents of chapatti (Table 4). On day 0 (fresh), the mean value of water soluble starch was 5.29%, and this decreased to 4.92% on day 7, followed by 4.53% on day 14, and 3.69% on day 28. These results were in agreement with the findings of Shaikh *et al.* (2007), who reported decreases in water soluble starch from 5.23% to 0.3% after one month of storage of chapatti at room temperature. In the present study, chapatti was stored at freezing temperatures (−18°C), which slowed the rate of decrease in water soluble starch. The decrease in water soluble starch in partially baked chapatti may be due to re-association of starch molecules from gels during storage, which eventually produce crystallites and gradually increase the rigidity and phase separation between polymer and solvent, known as syneresis (Colonna *et al.*, 1992). As storage duration increases, crystallites also increase, and this decreases water soluble starch.

Effects of hydrocolloids on sensory evaluation of fully baked chapatti after partial baking and frozen storage Table 5 shows that different treatments and storage intervals significantly ($p < 0.05$) affect the color of chapatti after 28 days of storage, although the interaction between storage interval and treatment was not significant with regard to sensory attributes. The mean values showing the effects of different hydrocolloids on color of fully baked chapatti after partial baking and frozen storage are given in Table 5. The mean color scores for chapattis range from 5.76 to 6.90 among different treatments and from 5.60 to 7.07 among different storage intervals with HPMC (Table 5 & 6). The highest color score was found to be 6.90 in T_3 (guar gum), followed by T_2 (CMC) with 6.69 and T_1 (HPMC) with 6.18 after 28 days of storage. However, lowest color score was 5.76 in T_0 (control sample). By comparing different treatments, it was found that guar gum showed the highest scores with whitish color, followed by CMC, HPMC and control with yellowish color. These results are supported by the findings of Habib and Butt (2003), who observed a significant role for guar gum in the color of chapatti. Selomulyo and Zhou (2007) also confirmed the effects of CMC and guar gum on bread color. However, Gill *et al.* (2006) reported that additives improved the color of chapattis. The decrease in color during storage may be due to the oxidation of fat, carotenoids and rancidity (Leelavathi *et al.*, 1984).

With regard to taste scores, the different treatments had no effect, but storage decreased the taste scores of chapattis after 28 days. As hydrocolloids have neutral taste, they did not impart any significant effects on taste. Anjum *et al.* (2003) reported similar deterioration in the taste of chapatti with storage.

Among different treatments, CMC containing chapatti had the highest scores for flavor, followed by T_1 (HPMC) and T_0 (control). The lowest scores for flavor were for T_3 (guar gum). Storage had a negative effect on flavor score, and this may have been due to the increase in free fatty acid, alcoholic acidity or lipase activity. Moreover, the high moisture content during storage favored hydrolytic rancidity (Leelavathi *et al.*, 1984).

The results indicated that hydrocolloids and storage interval significantly affect the texture of chapatti ($p < 0.05$); however, the interaction between treatments and storage was not significant. Partially baked chapattis made from HPMC had the highest scores for texture (Table 5), followed by chapattis prepared with CMC and guar gum. The lowest scores were seen in control chapattis (T_0). The results confirm that storage significantly affects the texture of chapatti; fresh chapatti scored highest for texture (8.05), and this decreased to 6.5 after 28 days of frozen storage in chapatti containing HPMC (Table 6). Similar results were reported by Barcenas and Rosell (2006). Another study also found that HPMC improve bread texture (Collar *et al.*, 1999; Dziezak, 1991). Selomulyo and Zhou (2007) demonstrated that the use of cellulose derivatives (HPMC and CMC) improve bread texture. Scores for texture decreased with storage, and this

Table 5. Effects of hydrocolloids on sensory evaluation of fully baked chapatti after partial baking and frozen storage

Treatments	Color	Taste	Flavor	Texture	Chewability	Foldibility	Over all acceptability
T_0	5.76 ± 0.1c	6.84 ± 0.2a	6.2 ± 0.1bc	6.44 ± 0.1c	6.58 ± 0.1b	6.38 ± 0.2c	6.32 ± 0.1d
T_1	6.18 ± 0.1b	7.00 ± 0.1a	6.56 ± 0.2ab	7.6 ± 0.3a	7.74 ± 0.1a	7.58 ± 0.1a	7.50 ± 0.3a
T_2	6.69 ± 0.1a	6.72 ± 0.4a	6.7 ± 0.2a	7.24 ± 0.1ab	7.44 ± 0.1a	7.28 ± 0.1ab	7.04 ± 0.3b
T_3	6.90 ± 0.1a	6.76 ± 0.1a	6.1 ± 0.3c	6.96 ± 0.1b	7.28 ± 0.1a	6.96 ± 0.3b	6.72 ± 0.1c

Scores with common letter in a column are not significantly different at the 5% probability level

Table 6. Effects of storage on sensory evaluation of fully baked chapatti containing HPMC after partial baking and frozen storage

Storage	Color	Taste	Flavor	Texture	Chewability	Foldability	Over all acceptability
Fresh	7.07 ± 0.2a	7.45 ± 0.1a	7.17 ± 0.1a	8.05 ± 0.3a	8.22 ± 0.3a	7.92 ± 0.4a	7.62 ± 0.5a
7th day	6.77 ± 0.1ab	6.95 ± 0.3b	6.82 ± 0.2ab	7.57 ± 0.2b	7.85 ± 0.2ab	7.52 ± 0.3b	7.12 ± 0.1b
14th day	6.47 ± 0.3b	6.8 ± 0.1bc	6.47 ± 0.3b	7.15 ± 0.4c	7.37 ± 0.2b	7.12 ± 0.1c	6.90 ± 0.4c
21st day	6.00 ± 0.3c	6.55 ± 0.4cd	5.97 ± 0.1c	6.62 ± 0.1d	6.8 ± 0.1c	6.65 ± 0.3d	6.56 ± 0.3d
28th day	5.60 ± 0.1d	6.4 ± 0.3d	5.57 ± 0.4d	5.90 ± 0.2e	6.05 ± 0.3d	6.02 ± 0.3e	6.28 ± 0.2e

Scores with common letter in a column are not significantly different at the 5% probability level deterioration in bread quality during storage was due to the transport of water from the hydrated gluten to the ice phase (Bot and De Bruijne, 2003).

The results indicated that hydrocolloids and storage interval significantly affect the chewability, foldability and overall acceptability of chapattis ($p < 0.05$); however, the interaction between treatment and storage was not significant. Scores for chewability, foldability and overall acceptability were highest in chapattis containing HPMC, followed by CMC and guar gum, and the lowest were for T_0 (control). HPMC and CMC considerably increased chewability scores, which was supported by the findings of Chinachoti (2005), who found that cellulose derivatives improve the mouth feel of bread. The improved chewability and foldability might be attributed toward the higher moisture retention capacity of these hydrocolloids. Similar results were reported by (Barcenas and Rosell (2006), who studied the softening effects of HPMC resulting from its ability to hold available water in the system. Cellulose-derived hydrocolloids considerably enhanced the sensory attributes that eventually improved the overall acceptability of chapatti (Selomulyo and Zhou, 2007). With storage, scores for these sensory parameters decreased and were found to be highest at the start and the lowed at the end of the experiment. Storage increases bread firmness, which is caused by the recrystallization of starch and redistribution of water. Similar results were reported by Ribotta *et al.* (2003), who found that low temperature storage causes an increase in bread firmness, which ultimately reduces its foldability and chewability.

Conclusion

Partial baking with hydrocolloids added to wheat flour and frozen storage is a good technique for improving the shelf life of chapatti. The addition of HPMC, CMC and guar gum to chapatti improves baking quality, shelf life and sensory attributes, as compared to controls, after a frozen storage period of 28 days. Among the hydrocolloids HPMC showed the most favorable results, followed by CMC and guar gum. These hydrocolloids and partial baking with frozen storage helped to improve the shelf life and quality of partially baked chapatti.

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