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Properties and Shelf-life of Part-and Full-baked Flat Bread (Barbari) at Ambient and Frozen Storage

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ABSTRACT

Production of part-baked bread is a successful method to postpone bread staling that has been applied widely for production of loaves. In this research, production and some physical characteristics of part-baked flat bread (Barbari) including hardness, volume, color, weight loss, and microstructure were studied during the storage of the samples at ambient (25ºC) and freezing (-18ºC) temperatures. The part-baked bread had higher moisture content than the control and full-baked breads. However, it had a shelf-life of 72 hours, which was shorter than the control at ambient temperature. Full-baking could level out the effects of staling and, hence, the quality of the full-baked bread was similar to that of the fresh bread. For the frozen samples, the optimum storage time was two months. The undesirable effects of frozen storage were more significant for the part-baked bread. Moreover, full-baking could compensate some of the adverse effects of freezing and the resultant bread had superior quality compared with the control.

Keywords*:* Barbari bread, Flat bread, Full-baking, Part-baking, Shelf-life.

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INTRODUCTION

Bread, the main food around the world, is produced in two main shapes; loaf and flat. Loaf bread is common in European and many American countries, while flat bread is consumed widely in Asian countries. Flat bread has a large surface area and a very thin crumb. Barbari is a well-known flat bread produced in many parts of the world such as Iran, Turkey, and some Arab countries. It is produced in a round or oval shape with thickness of 0.5 to 2 cm and up to 100 cm long (Qarooni, 1996). It is vary palatable when freshly baked, however, it losses its quality and stales quickly within a few hours after baking and, hence, its spoilage is very high. Therefore, increasing the shelf-life of Barbari bread is of great importance.

One of the main causes of bread spoilage is bread staling. This phenomenon has been studied for many years and the results indicate that the main reasons for bread staling are starch retrogradation, formation of starch-gluten cross-linkages and water migration from bread crumb to its crust (Martin *et al*., 1991; Martin and Hoseney, 1991; Hoseney, 1994; Gray and Bemiller, 2002; Willhoft, 1971).

To delay bread staling and increase bread shelf-life, different bread additives and technological methods have been applied (Rogers *et al*., 1988; Hoseney, 1994). One of the possible methods is to use frozen storage. This method is an appropriate method for long-term storage of bread (e.g. 3-4 weeks). Freezing converts the water in the bread into a non active compound and this, along with the low temperature, retard microorganism growth and prevent chemical and enzymatic deterioration of bread (Barcenas and Rosell, 2006). However, after defrosting of the frozen bread, it can not

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retrieve all the qualities of the freshly baked bread (Hug-Iten *et al*., 2003).

Another technique to increase the shelf-life of bread is part-baking. Since 1990, part-baked bread, which is also called interrupted- or par-baked bread, has been introduced in which the bread is partially baked so that baking is just interrupted before formation of crust color, i.e. before Millard and caramelization reactions (Vulicevic *et al*., 2004; Barcenas and Rosell, 2004). The part-baked bread is then packed and can be kept at ambient temperature for several days or chilled and frozen for long storage (several weeks) before full-baking by the consumers. Although there are some problems with the quality of part-and re-baked breads, e.g. crust flaking, reduction in bread volume, and rapid staling after full-baking (Guarda *et al*., 2004; Barcenas, *et al*., 2003; Le Bail *et al*., 2005), this method has been successfully used for production of different types of loaves and, recently, for cakes (Barcenas, *et al*., 2003; Farahnaky and Majzoobi, 2008**;** Karaoglu *et al*., 2008; Karaouglu and Kotancila, 2009). Regarding the popularity of part-baked bread, several studies have been conducted to determine the appropriate time and temperature for part-baking (Ferreira *et al*., 1999; Fik and Surowka, 2002), quality of bread after full-baking (Fik and Surowka, 2002) and its microbial quality (Doulia *et al*., 2000; Leuschner *et al*., 1999). There is little published research on the production, properties, and storage of part-baked flat breads. Recently, Gujral *et al*. (2008) studied the effect of conventional and part-baking and storage temperature on the texture of Chapatti bread, which is a flat and chemically leavened bread. They reported that part-baking was a better option than the conventional freezing method to retard staling.

The main aim of the present research was to study the effect of part baking on bread quality in terms of hardness, volume, baking weight loss, color, microstructure, and shelf-life of Barbari as a common flat bread stored at ambient and freezing temperatures.

MATERIALS AND METHODS

Materials

Wheat flour appropriate for production of Barbari bread was purchased from Sepidan Milling Factory, Fars Province, Iran, with extraction of 82% (according to the manufacturer) and protein content of 12.2% on dry basis (as determined by the approved methods of AACC 2000). Active dry yeast, salt, and bread improver (Novo Ferment AG, Switzerland, containing malt extract, gluten, ascorbic acid, corn starch and tartaric acid), and polyethylene bags with thickness of 50 µm were obtained from local market. Other chemicals used in this study were purchased from Merck Company (Germany) and were of analytical grade.

Methods

Dough Preparation

The exact amount of water required to make bread dough was first determined by a Farinograph (Model FE022N, Germany) according to the approved methods of AACC, 2000. Then, the dough was made by mixing wheat flour, water (62% as determined by a Brabender Farinograph according to the AACC method, 2000), salt (2% w/w, flour basis), bread improver (0.2% w/w, flour basis) and activated yeast (2% w/w, flour basis) in a laboratory dough mixer at 140 rpm at 30ºC for 15 minutes. Then the dough was proofed in a proofing cabinet at relative humidity of 80% and 40ºC for 45 minutes, divided into portions of 400 g, rounded by hand and placed in the proofing cabinet once again for 45 minutes. The dough pieces were shaped in the form of circle with a thickness of 1.5 cm and diameter of 40 cm.

Part-baking of Bread

To part-bake the bread, the dough was baked in an electrical baking oven (Model

Karl Welkerkg, Germany) at a relative humidity of more than 90%. At this stage, the bread was baked without development of any bread flavor or color on the crust. By trial and error, the appropriate time and temperature were determined to be 7 minutes at 210°C. A control sample was also prepared with the same method, but it was baked at 210°C at a relative humidity more than 90% until the crust color and bread aroma were fully developed (took 20 minutes). After that, the part-baked and the control breads were cooled down at room temperature for 1 hour and sealed in polyethylene bags for further experiments. The part-baked and the control breads had a thickness of about 2 cm.

Full-baking and Storage of the Part-baked Bread

To determine the effects of storage conditions on the breads, some of them were stored at 25°C (in an incubator, Model General Electric, Iran) until mould growth was observed on the samples. A control sample was also stored under the same condition. To determine the physicochemical properties of these samples, every 24 hours, a part-baked bread was full-baked at 240°C for 15 minutes at a relative humidity more than 90%. At this stage, bread flavor and crust color were developed and the full-baking was stopped as soon as the color and flavor were produced. After full-baking, samples were left for 1 hour to cool down at room temperature for further experiments.

To study the effect of freezing on the samples, some of the part-baked and control samples, were frozen quickly using a high speed plate freezer (model DOLE, Freezer Cell, Canada). The frozen control and part-baked breads were then stored in a freezer (Model General steel, Iran) at -18°C for up to four months. Each month, sufficient numbers of part-baked breads were removed from the freezer and left at room temperature (20±2°C) for 1 hour and then full-baked at 240°C for 15 minutes at a relative humidity more than 90%, during which bread flavor and crust color were developed. The full-baked breads were left at room temperature to cool down for 1 hour, and then further experiments were performed. At the same time, the control sample was also removed from the freezer and defrosted at room temperature for 1 hour before any experiments.

Determination of the Quality of the Full-baked and Control Breads

Moisture Content

To determine the moisture content of different layers of the bread, upper and lower crusts were removed from the bread with the thickness of 0.5 cm each (from the upper and the lower surface, respectively) and the rest was the crumb. Then, the moisture content of each layer was determined by oven drying at 105ºC until constant weight.

Microstructure of Bread

To study the microscopic structure of the bread crumb, scanning electron microscopy (SEM) (Model 5526, Mark Cambridge, UK) was used. Samples were prepared by freeze drying a thin layer of the bread and then sputter coating of a small piece of the sample with gold. Finally, the sample was transferred to the microscope where it was observed at 20 kV.

Bread Volume

The volume of the bread samples was determined using the rapeseed replacement method according to Lee *et al.* (1982).

Hardness of the Breads

A penetration test using a cylindrical probe with diameter of 10 mm was performed to determine crust and crumb hardness using a Texture Analyser (Model Stevens-LFRA, UK). To study crust hardness, a piece of bread with its crust was used for the experiment. Probe speed and penetration depth were 1 mm s^{-1} and 2 mm,

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respectively. To determine crumb hardness, 0.5 mm of the upper crust was cut and removed and the underneath crumb was used for the experiment. For this reason, probe speed and penetration depth were 1 mm s^{-1} and 10 mm, respectively. The experiment was performed at five different points of the bread crust and crumb and the average value was reported.

Freezing Weight Loss

The weight of the bread (or part-baked bread) was determined before and after freezing and then, according to the Equation (1), the freezing weight loss (%) of the samples during freezing was obtained (Phimolsiripol *et al*., 2008).

$FWL = 100 \times (W_{bf} - W_{af}) / W_{bf}$ (1

Where,

FWL= Freezing weight loss (%);

W_{bf} = Weight of the samples before freezing (gr),

W_{af} = Weight of the samples after freezing (gr).

Baking Weight Loss

To determine the baking weight loss of the samples, the weight of the piece of bread dough before baking and the weight of the baked (or full-baked) breads after cooling for 1 hour at room temperature, were determined. Then the baking loss was obtained according to the Equation (2).

$BWL = 100 \times (W_d - W_b)/W_d$ (2

Where,

BWL= Baking weight loss (%);

W_d= Weight of piece of dough (gr),

W_b= Weight of bread (or full-baked bread) (gr).

Crust Color

The color of bread crust was evaluated using a modified method of Yam and Papadakis (2004). High resolution pictures of whole bread crust were taken separately from bread surface by a digital camera (Fujifilm, 2.0 Megapixels, China). Resolution, contrast and lightness of all images were set to 300 dots per inch (dpi), 62 (%) and 62 (%), respectively. The pictures were saved in JPEG format and analyzed quantitatively using the Adobe Photoshop 8 software installed on a Pentium 4 computer and the color parameters of "*L*" (lightness), "*a*" (redness-greenness) and "*b*" (blueness-yellowness) were determined in the "Lab" mode of the software.

Sensory Analysis

General acceptability of the breads stored under different conditions was studied by sensory evaluation with 12 in-house panelists using a seven-point hedonic scale. The panelists were familiar with the sensory evaluation methods and were further trained how to judge the bread samples. The samples were first coded with three digits random numbers and were given to the panelists, simultaneously. The test was performed in a standard booth under day light illumination (Watts *et al*., 1989). The panelists were asked to give the highest score to the most acceptable sample and the lowest score to the least acceptable one. Since mould growth was observed on some of the bread pieces stored for longer than 72 hours at 25°C, these samples were not used for sensory evaluation.

Statistical Analysis

The experiments were performed in a completely randomized design. All experiments were conducted in triplicates and the mean values and standard deviations were reported. Analysis of variance (ANOVA) was performed and results were separated using the Multiple Ranges Duncan's test ($\alpha < 0.05$) using statistical software of Statistical Package for the Social Sciences (SPSS), Version 16; (SPSS, Inc. New Jersey, USA).

RESULTS AND DISCUSSIONS

Moisture Content

Determination of the moisture content of different parts of the bread (Figure 1) showed that the part-baked bread had higher

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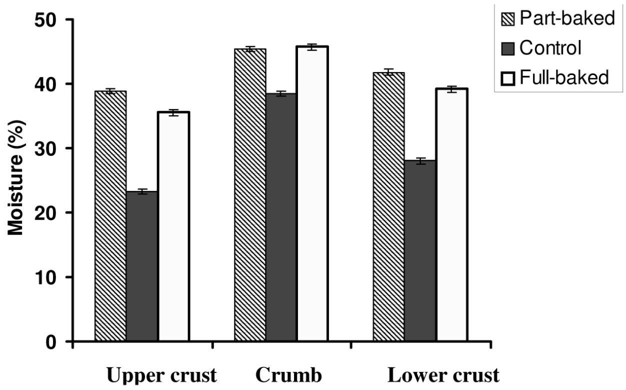

Figure 1. The moisture content of upper crust, crumb, and lower crust of the part-baked, full-baked, and the control samples.

moisture content compared to the other samples. This can be attributed to the shorter baking time of the part-baked samples (7 minutes) compared to that of the control (20 minutes) and, hence, higher moisture may remain in the samples. This is in agreement with Barcenas and Rosell (2006). Moreover, the moisture content of the full-baked bread was higher than the control. The final moisture content of the full-baked bread depends on the temperature and time applied for full-baking, which has a great impact on the properties of the bread. The upper crust of all these samples had the lowest moisture content compared to the other parts, while, the crumb had the highest moisture content. In general, the bread crust is directly in contact with the hot air in the oven and, hence, losses water readily during baking time and forms a hard texture on the surface of the baking bread. However, the crumb is exposed to less severe heating during baking and, hence, loses less water compared to the crust. Formation of crust on the surface of bread also prevents further water loss of the crumb.

Microstructure of Bread Samples

Figure 2-A shows the micrograph of the gas cell wall of the fresh control bread. In this picture, it is possible to differentiate starch granules surrounded by the denatured gluten matrix and, in general, the structure looks fairly smooth and continuous. Similar structure was also reported by Gray and Bemiller (2003), Rojas *et al*. (2000), and Barcenas and Rosell (2006) for fresh and part-baked bread. However, after 4 days of storage at ambient temperature, a wrinkly structure could be seen as a result of bread staling (Figure 2-B), which may cause bread hardness and reduction in bread volume. The microstructure of the gas cell walls of the fresh part-baked bread is depicted in Figure 2-C. The structure is similar to that of the fresh control with a continuous structure. Similar structure was also observed by Gray and Bemiller (2003) and Barcenas and Rosell (2006) for fresh part-baked breads. However, when it was stored at ambient temperature for 4 days, bread staling occurred and some wrinkles could be seen on the cell walls of the sample (Figure 2-D). Therefore, part-baked bread also undergoes staling during the storage time. After 4 days of storage at ambient temperature, the part-baked bread was fully baked and the results indicated that the wrinkly structure was replaced by a moderately smooth structure as a result of full-baking (Figure 2-E). It has been indicated that the heating during baking of part-baked bread can melt some starch crystals generated during staling (Fik and Surowka, 2002). Therefore, the structure became smooth and soft and the signs of staling may have disappeared.

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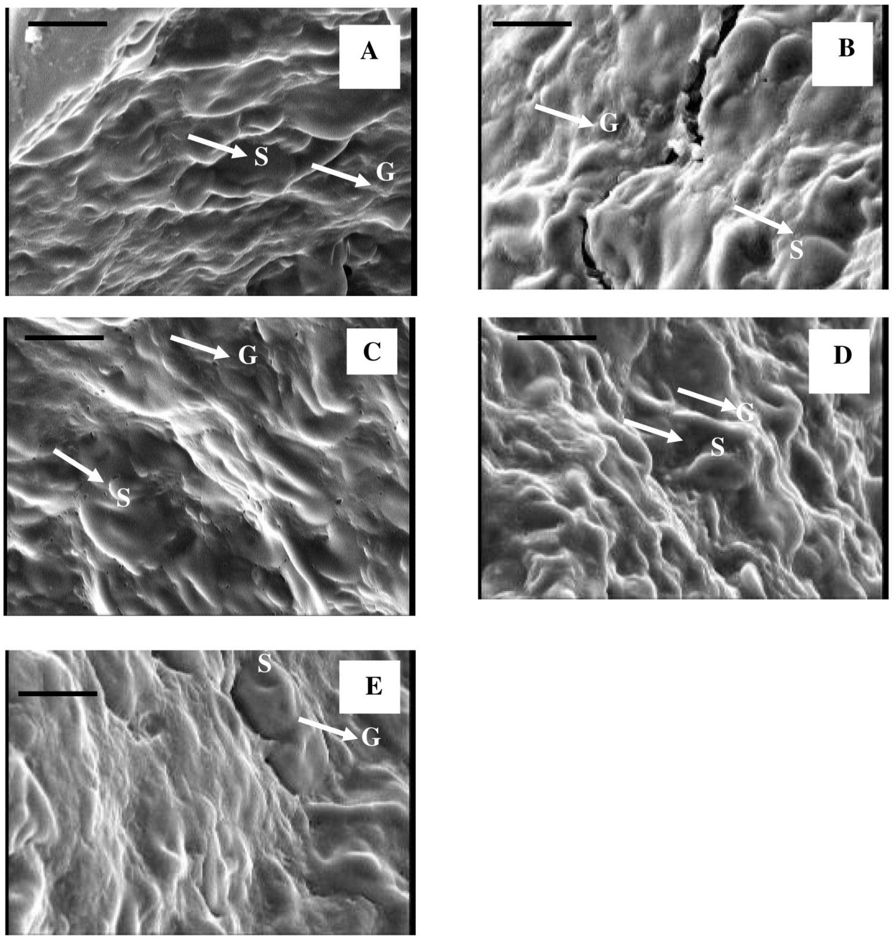

Figure 2. Electron micrographs of the gas cell walls of the bread samples stored at ambient temperature. (A): Control; (B): Control after 96 hours; (C): Part-baked bread; (D): Part-baked bread after 96 hours, (E): Full-baked bread obtained from part-baked bread stored for 96 hours. Each bar on the micrographs represents 20µm. S= Starch granules, G= Gluten.

Determination of the microstructure of the frozen samples showed that freezing had some effects on the gas cell walls of the frozen samples. The results showed that after 4 months of frozen storage, the fairly smooth structure of fresh control (Figure 3-A) and part-baked (Figure 3-B) samples changed clearly (Figures 3-C and -D, respectively). This can be attributed to the destruction of gluten network as a result of ice crystal formation. Accordingly, some of the starch granules were deformed and gluten network was damaged. Damage to the starch granules in the frozen dough was also reported by Berglund *et al.* (1991). Moreover, the starch granules are more visible in these pictures as a result of destruction of gluten network. Similar observations were also reported by Barcenas and Rosell (2006) who indicated that the microstructure of frozen bread confirms the presence of ice crystals that damage the crumb structure, mainly gluten network. It has been reported that the amount of freezable water increases during frozen storage of dough (Ribotta *et al*., 2003) and part-baked bread (Barcenas *et al*., 2003), which can turn into the ice crystals. Since the gluten network has already been denatured in the part-baked bread before freezing, the main reason for increasing the freezable water in part-baked bread during freezing is the redistribution of water in the system (Barcenas *et al*., 2003).

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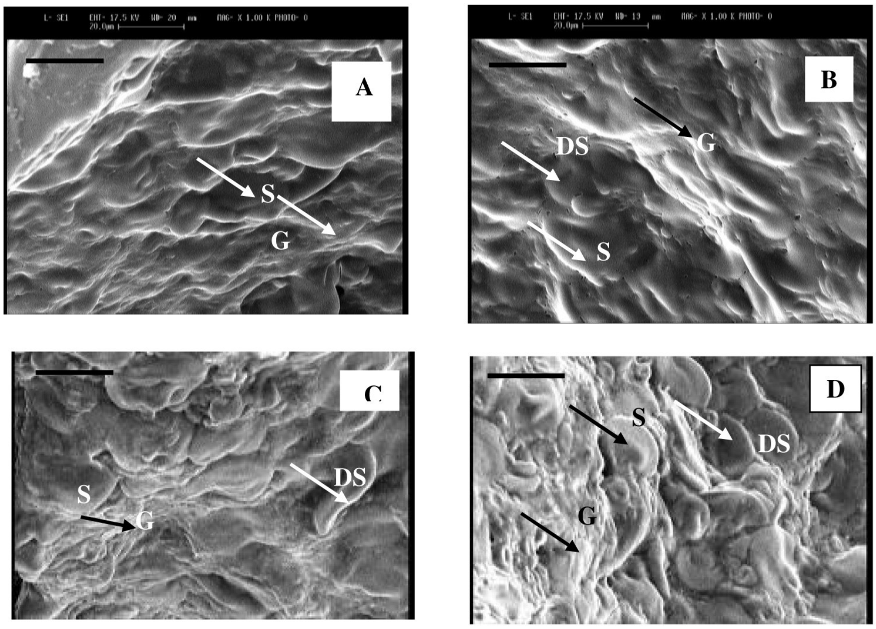

Figure 3. Electron micrographs of the gas cell walls of the bread samples. (A): Fresh control; (B): Fresh part-baked bread; (C): Control after 4 months of frozen storage, (D): Part-baked bread after 4 months of frozen storage. Each bar on the micrographs represents 20µm. S= Starch granules; DS= deformed starch granules, G= gluten network.

Determination of Bread Volume

The volume of the part-baked and the control breads produced from 400 g of dough was 785.33 ± 1.02 cm^3 and 783.16 ±1.60 cm^3, respectively. Since these values were not significantly different ($\alpha < 0.05$), it can be concluded that during part-baking, the bread reached its final volume. After full-baking, the volume of the samples was determined and, as Figure 4-A and -B show, the volume of the full-baked breads was less than the control when stored either at ambient or freezing temperatures. Therefore, when the part-baked bread was fully baked, a reduction in the volume was observed. The results are in agreement with Ribotta and Le Bail (2006) who indicated that thermal shock during full-baking can cause reduction in the volume of full-baked breads.

At ambient temperature, the volume of the control sample decreased slightly over the storage time (Figure 4-A). Reduction of the bread volume is an indication of bread staling, which is more pronounced after 72 hours of storage. It has been reported that staling can happen for part-baked bread during the storage time and hence cause reduction in bread volume (Karaoglu, 2006). However, at ambient temperature, no reduction in the volume of the full-baked breads was observed. This might be related to the full-baking stage during which a portion of bread water may evaporate and hence compensate for the reduction of the volume that occurred as a result of staling before full-baking. The results also indicate that the part-baked bread could not be stored at ambient temperature for longer than 72 hours because of the mould growth on the surface of the samples, whereas, the control could be kept at ambient temperature for longer time i.e. 96 hours,, probably due to the higher moisture content of the part-baked bread compared to the control (as shown in previous section).

Figure 4-B shows that the volume of the control sample stored at freezing temperature reduced particularly after 2 months of storage, perhaps as a results of the formation and growth of ice crystals in the

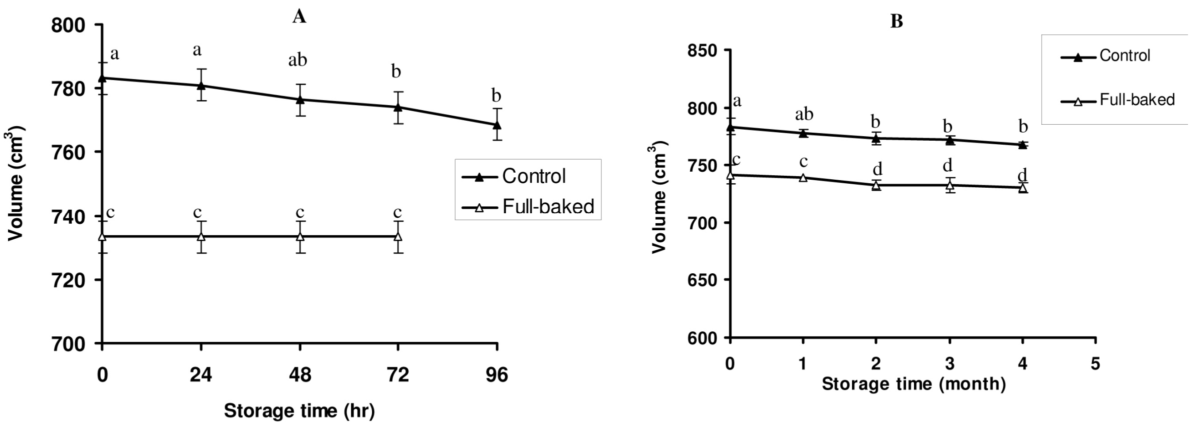

Figure 4. Volume of the bread samples stored at ambient temperature (A) and in freezer (B). Different letters on each graphs show the statistical difference between each sample (α <0.05).

bread during freezing. The ice crystals can damage and destroy the gluten network and deform starch granules (see also the micrographs). Consequently, the volume of the bread may reduce during long term freezing. For the part-baked frozen breads similar scenario may occur, however, as the part-baked bread contained more water than the control, the damage caused by ice crystals was more pronounced and the volume of the full-baked bread was significantly lower than the control. Increasing the storage time in the freezer further reduced the volume of the full-baked bread, which was noticeable after two months of storage.

Bread Hardness

Figure 5 shows that, in general, the full-baked bread had softer crumb compared to the control. This can be attributed to the higher moisture content of this sample (as determined in previous results). It has been indicated that water acts as plasticizer in the bread. Therefore, decrease in the moisture content favors the formation of hydrogen bonds among the starch polymers or between the starch and proteins, resulting in greater hardness (Schiraldi and Fessas, 2001). The result of this experiment is in agreement with Carr and Tadini (2003) who reported softer texture for full-baked bread compared to the

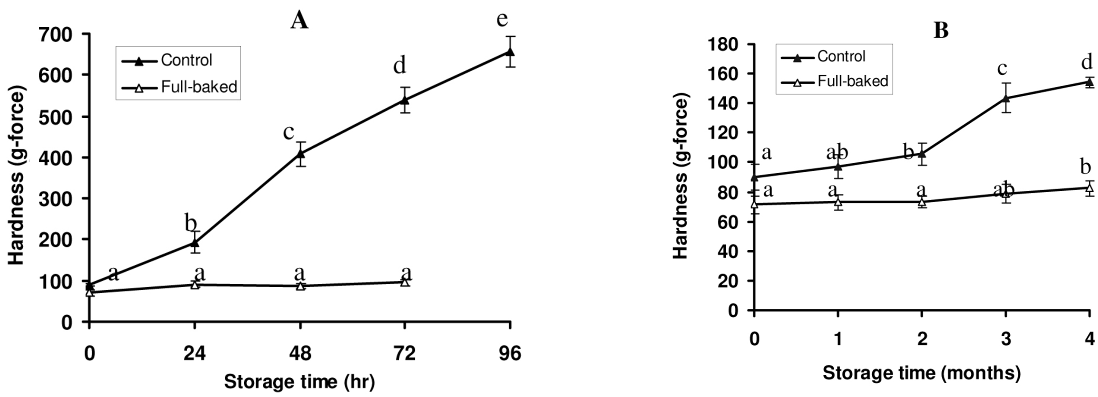

Figure 5. Crumb harness of the bread samples stored at ambient temperature (A) and in freezer (B). Different letters on each graphs show the statistical difference between each sample (α <0.05).

control. Moreover, the results show that at ambient temperature, the hardness of the control increased significantly during the storage of the samples (Figure 5-A). This increase is an indication of bread staling that is caused mainly by starch retrogradation, formation of cross-linkages between starch and gluten chains, and water migration towards bread crust (Karaoglu and Kotancilar, 2006). However, under the same condition, no significant increase in the crumb hardness of the full-baked breads was observed, possibly because of full-baking of these samples before determination of the bread hardness. It has been reported that the process of starch retrogradation or bread firming can be reversed when bread is heated at above 55 ºC (Ghiasi *et al*., 1984). Therefore, heating can melt some of the starch crystals formed during the staling of part-baked bread, thereby causing the full-baked bread to become softer compared to the control.

Figure 5-B shows that the crumb hardness of the control increased slightly after 2 months of storage in the freezer. In frozen products, the hardness of crumb and crust is due to the structural changes of starch, protein and the loss of moisture. It has been reported that the starch granules may be damaged by the ice crystals, which increases with the time of frozen storage. This allows amylose leaching from the granules and, hence, formation of a network of amylose that bring about an increase in the crumb hardness. Another reason for crumb hardness is the growth of ice crystals during the frozen storage that can damage the protein network formed by the denatured proteins. (Barcenas and Rosell, 2006). Barcenas *et al*. (2003) and Vulicevic *et al*. (2004) indicated that the time of frozen storage determines the hardness of bread during aging. Fik and Surowka (2002) reported that frozen storage shorter than 11 weeks had the least effects on the texture of bread after full-baking. The results also show that the full-baked bread had softer texture than the control. This is in agreement with Fik and Surowka (2002) who indicated that full-baking can level out most of the possible changes that occurred during frozen storage of the samples.

Comparison of Figure 5-A and –B indicates that the hardness of frozen breads was significantly less than the hardness of the samples stored at ambient temperature. This may indicate that the staling process (at ambient temperature) had greater effect on bread hardness than the damage to the gluten network and starch granules caused by ice crystals during freezing. Starch retrogradation, water migration from crumb to the crust, formation of some interaction between starch molecules and proteins, and shrinkage of the air bubbles of bread crumb are the main factors affecting bread hardness during staling.

Baking and Freezing Weight Loss

Determination of the baking weight loss of the samples indicated that the control and the part-baked breads had baking weight loss values of 21.3±0.1% and 15.8±0.2% w/w, respectively. Therefore, baking weight loss of the control was higher than the part-baked bread as the result of longer baking time.

During the storage time in the freezer, the weight of both samples decreased with increasing the freezing time (determined as freezing weight loss). The freezing weight loss of the part-baked bread was 0.45% after one month of storage, while it increased significantly to 2.50% after four months (Figure 6). For the control, the freezing

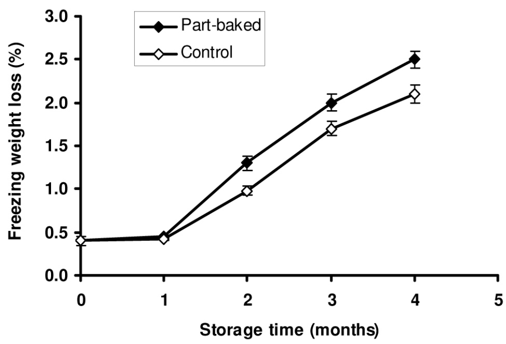

Figure 6. Freezing weight loss of the part-baked and control samples during storage time in freezer.

weight loss increased from 0.40% after the first month of storage to 2.10% at the last month of freezing. Therefore, the part-baked bread had more freezing weight loss than the control. These findings are in agreement with Vulicevic *et al*. (2004) and Barcenas *et al*. (2003). Phimolsiripol *et al*. (2008) reported a freezing weight loss value of 1.5% for loaf breads after 4 months of freezing. Freezing weight loss can be attributed to the reduction of the water retention capacity of the bread constituents and increase in the amount of free water molecules which can convert to ice crystals (Lu and Grant, 1999; Ribotta *et al*., 2003; Bhattacharya *et al*., 2003).

Although the part-baked breads had higher freezing loss than the control, no significant baking loss was observed for these samples after full-baking (data not shown). On the other hand, full-baking did not reduce the weight of the bread any further. This is in agreement with Carr *et al*. (2005), who indicated that high humidity applied in an oven during full-baking can compensate for the freezing weight loss of the samples, therefore, the weight of these samples remained the same.

Color of the Samples

The results of determination of the crust color of the samples stored at ambient temperature are presented in Table 1 and show that, during the storage, the crust L-value (lightness) of the control dropped significantly. This can be attributed to the starch retrogradation on the surface of the bread and increasing the moisture content of the bread crust as the result of water migration from bread crumb to the crust during bread staling. Furthermore, increase in the a-value (redness-greenness) and decrease in the b-value (blueness-yellowness) may be related to the migration of some water from the crumb to the crust. Increasing the moisture content of bread crust as a result of staling can affect the color parameters of the sample.

For full-baked bread, no significant change in crust color was detected. Thia could be related to the full-baking of bread and formation of the color just before determination of bread color parameters, consequently, storage time would not have any effect on full-baked bread crust.

Determination of the color parameters of the control samples stored in the freezer (Table 2) showed that the crust L-value increased with increasing the storage time and the bread crust became lighter during storage of the bread. Reduction of the L-value may be related to the formation of ice crystals on the surface of the bread and hence increase the whiteness i.e. higher L-value, of the crust. Moreover, a- and b-values decreased during storage time. On the other hand, frozen storage caused reduction in the redness and yellowness of the bread crust. Reduction in the color of the control may be attributed to the destruction of some color pigments as a result of formation and growth of ice crystals, particularly on the surface of the bread during freezing. In contrast, no significant changes in the color parameters of the full-baked breads were detected. This can be related to the formation of color pigments during full-baking of the samples. Therefore, storage

Table 1. Color parameters of the crust of the bread samples stored at ambient temperature [a].

Storage time (hr)	L		a		b	
	fb [b]	C [c]	fb	C	fb	C
0	50.2[a]	60.8[a]	7.8[a]	2.2[a]	40.6[a]	45.2[a]
24	50.0[a]	58.6[b]	7.4[a]	3.2[b]	40.5[a]	43.8[b]
48	49.2[a]	55.4[c]	8.2[ab]	5.2[c]	40.2[a]	42.8[c]
72	50.8[a]	50.8[d]	7.6[a]	6.6[d]	39.8[a]	42.2[d]

[a] Different letters in each column indicate significant difference of the data (α< 0.05). [b] Full-baked bread, [c] Control.

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Table 2. Color parameters of the crust of the frozen bread samples [a].

Storage time (month)	L		a		b	
	fb [b]	C [c]	fb	C	fb	C
1	51.4[a]	56.4[a]	6.6[a]	-0.2[a]	36.2[a]	38.8[a]
2	51.8[a]	58.8[b]	6.4[a]	-1.0[b]	35.6[a]	36.4[b]
3	52.2[a]	61.2[c]	6.8[a]	-1.2[b]	35.8[a]	31.2[c]
4	51.2[a]	62.4[d]	6.4[a]	-2.8[c]	35.4[a]	29.6[d]

[a] Different letters in each column indicate significant difference of the data ($\alpha < 0.05$). [b] Full-baked bread, [c] Control.

time in the freezer had no effect on the crust color of the full-baked breads.

General Acceptability of the Samples

The results of determination of consumers' acceptability of the samples stored at ambient temperature (Table 3) revealed that, with increasing the storage time, the general acceptability of the control decreased, while no significant changes in the general acceptability was observed for the full-baked bread. This can be attributed to the reduction in the overall quality of the control bread due to the staling, while full-baking can compensate for the quality loss of the samples caused by staling. Moreover, the full-baked breads were more acceptable than the control during the storage time.

For frozen samples (Table 4), it was found that increasing the storage time caused reduction in the general acceptability of both samples. Vulicevic *et al*. (2004) also reported a significant reduction in the sensory quality of the frozen part-baked breads particularly after one month of storage. Comparison of the values obtained for the control and the full-baked breads showed that the latter was more acceptable for the first two months. After that, its acceptability decreased significantly and it received similar scores to that of the control. This could be due to the inferior bread quality as a result of freezing and is in agreement with the findings of Vulicevic *et al*. (2004). However, Fik and Surowka (2002) found no significant correlation between the overall sensory parameters and the frozen storage time.

CONCLUSIONS

From the aforementioned results, it can be concluded that the crumb structure of bread is fully formed during part-baking stage. Moreover, staling can occur for part-baked bread during storage at ambient temperature. However, after full-baking, many signs of staling disappeared and the bread had softer texture, and better crust color, taste, and flavor. Reduction in bread volume after full-baking, which is a major defect for part-baked loaves, had no effect on the consumers' acceptability of Barbari bread since it is a kind of flat bread. Although the shelf-life of part-baked bread at ambient temperature was shorter than the control, the resulting full-baked bread was of higher quality.

During frozen storage, the damage caused

Table 3. General acceptability of the samples stored at ambient temperature. [a]

Sample	Storage time (hr)				
	0	24	48	72	96
Control	6.1[aA]	5.5[bB]	4.0[cC]	3.3[dD]	2.0[E]
Full-baked	6.5[aA]	6.0[aB]	6.0[aC]	5.7[aD]	-

[a] Values in the table are the average of triplicates. Capital letters show significant difference between the values in each row. Small letters shows significant difference between the data in each column ($\alpha < 0.05$). (6-7)= Excellent; (5-6)= Very good; (4-5)= Good; (3-4)= Average; (2-3)= Fair; (1-2)= Bad, (0-1)= Very bad.

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Table 4. General acceptability of the frozen samples after defrosting of the control and full-baking of the part-baked bread samples. [a]

Sample	Storage time (months)				
	0	1	2	3	4
Control	6.0 aA	5.2 aB	4.8 aB	4.3 aB	3.5 aC
Full-baked	6.5 bA	6.0 bA	5.5 bB	4.5 aC	3.8 aD

[a] Values in the table are the average of triplicates. Capital letters show significant difference between the values in each row. Small letters shows significant difference between the data in each column (α <0.05). (6-7)= Excellent; (5-6)= Very good; (4-5)= Good; (3-4)= Average; (2-3)= Fair; (1-2)= Bad, (0-1)= Very bad.

by the growth of ice crystals is more pronounced for the part-baked bread, resulting in deterioration of bread quality. To reduce such effects, it is suggested to store part-baked breads in freezer no longer than 2 months. After full-baking, the bread had better quality than the control. In general, frozen breads had better quality attributes than those stored at ambient temperature.

The reduction in the volume caused by frozen storage and full-baking was not of great importance since Barbari bread still received higher scores than the control in terms of general acceptability. This may indicate the more important role of the other quality attributes of the flat bread, e.g. color and texture as studied in this research, on general acceptability.

Overall, the results of this study suggest that part-baking can be an appropriate method to preserve the quality of Barbari bread for longer time and to delay its staling. Further studies are required to show the possibility of part-baking of other types of flat breads such as Lavash and Taftoon, which have no crumb.

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خصوصیات نان نیم پخته و پخت کامل شده مسطح (بربری) و ماندگاری آن در دمای محیط و انجماد

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چکیده

تولید نان نیم پخته یک روش موفق برای تعویق بیاتی نان می باشد که تا کنون برای تولید نانهای حجیم بکار رفته است. در این تحقیق تولید و برخی خصوصیات فیزیکی نان مسطح نیم پخته (بربری) شامل سفتی ، حجم ، رنگ ، افت وزن و ساختار میکروسکوپی در طی نگهداری در دمای محیط (۲۵°C) و انجماد (۱۸°C-) مطالعه شد. نان نیم پخته دارای رطوبت بالاتری از نمونه شاهد و نان پس از پخت کامل بود. اگرچه نان نیم پخته ماندگاری کوتاهتری نسبت به نمونه شاهد در دمای محیط داشت که این زمان ۷۲ ساعت بود. پخت کامل این نان سبب شد که اثرات بیاتی آن از بین برود و لذا کیفیت نان پس از پخت کامل شبیه به نان تازه بود. زمان مناسب جهت نگهداری نان به صورت منجمد دو ماه بود. بعلاوه پخت کامل توانست برخی از اثرات نامطلوب مربوط به انجماد را جبران نماید و نان حاصل دارای کیفیت بهتری نسبت به نان کنترل بود.

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