Staling and Quality of Iranian Flat Bread Stored at Modified Atmosphere in Different Packaging

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Abstract**—**This study investigated the use of modified atmosphere packaging (MAP) and different packaging to extend the shelf life of Barbari flat bread. Three atmospheres including 70%CO_2 and 30%N_2, 50% CO_2 and 50%N_2 and a normal air as control were used. The bread samples were packaged in three type pouches. The shelf life was determined by appearance of mold and yeast (M +Y) in Barbari bread samples stored at 25 ± 1°C and 38 ± 2% relative humidity. The results showed that it is possible to prolong the shelf life of Barbari bread from four days to about 21 days by using modified atmosphere packaging with high carbon dioxide concentration and high-barrier laminated and vacuum bags packages. However, the hardness of samples kept in MAP increase significantly by increase of carbon dioxide concentration. The correlation coefficient (r) between headspace CO_2 concentration and hardness was 0.997, 0.997 and 0.599 for A, B and C packaging respectively. High negative correlation coefficients were found between the crumb moisture and the hardness values in various packaging. There were significant negative correlation coefficients between sensory parameters and hardness of texture.

Keywords**—**modified atmosphere packaging, flat bread, Iranian bread, staling, correlation.

I. Introduction

SHELF life of perishable foodstuffs such as meat, fishery, vegetables, and bakery products packed in normal atmosphere, is mainly limited by two factors: atmospheric oxygen effect and the growth of aerobic spoiling microorganisms [1]. Staling refers to a broad set of sensory and chemical changes that affect the crispiness of the crust, the textural properties of the crumb and the aroma [2]. Modified atmosphere packaging (MAP) of bread is known to extend the microbial shelf-life [3]. Reduction of oxygen is one of the primary uses of active packaging and MAP for nonsterile foods [4]. Although CO_2 is not known to be lethal to microorganisms, it has shown both bacteriostatic and fungistatic properties and will hinder the growth of certain aerobic organisms [5]. For this reason there is an increasing demand for storage of bread in modified atmospheres, which is most often composed of CO_2 alone or mixtures of CO_2 and N_2 [3]. However, the effect of MAP on the physio-chemical quality changes occurring during storage of bread is questionable [3]. Reference [6] shows that crumb firmness of white and wholemeal bread stored in CO_2 for 14 days was lower than bread stored in N_2 or in atmospheric air. Similar results were obtained by [7], who found that crumb firmness of white pan bread stored in CO_2 for 10 days was lower compared with bread stored in atmospheric air. Contrary to these findings, [8] did not find any differences in the firming rate of pita bread stored in CO_2 or atmospheric air for 14 days. Reference [3] found No significant effects of MAP during storage of bread for 7 days at 20 ^{0}C compared to control bread. The mechanism of bread firming is complex and not well understood. Reference [9] suggested that bread firming might be a result of starch-gluten interactions, where gluten is cross-linked by gelatinized starch. However, Reference [10] showed that starch bread without gluten will firm at a similar rate compared to bread with gluten. They suggested that gluten interaction with starch was not essential for the increasing in firmness and starch retrogradation is sufficient to cause bread firming. One factor that may affect the staling process is the difference in water content and mobility between two breads [11]. Although firming of bread crumb is known not to be due to the loss of moisture, it is a fact that the firming rates as well as the rate of starch recrystallization are sensitive to the actual water content during [12]- [15]. Rate of firming has an inverse relationship to crumb moisture content [14]. Moisture migrated during storage from crumb to, and within bread constituents [7], [16], [17]. Reference [18] reported a correlation between local moisture content and texture of stale bread. They concluded that slowing the dehydration rather than increasing the initial moisture content prevented staling. Reference [19] found a strong correlation between the staling rate of bread and moisture content. Also [20] concluded that bread with higher moisture content was significantly fresher than bread with a lower content. Reference [21] found good correlation between sensory and Instron measures of bread. In contrast [22] obtained low correlation coefficients between measures of textural parameters of rye and French bread using a sensory panel and Instron compression techniques. The objective of our study

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was to evaluate the effect of MAP and various packaging films on the staling and shelf life of Barbari bread. Also the correlation coefficient (r) evaluated between sensory parameters and instrumental texture parameters. Moreover, a correlation coefficient (r) test was carried out to evaluate relationships crumb moisture, headspace gas composition and hardness throughout time. To meet this objective, we conducted shelf life studies during a 21-day storage period.

II. Materials and Methods

A. Materials

Commercial Triticum aestivum wheat flour with 10.52% (w.b.) moisture, 12.8% protein, 1.76% lipid, 0.79% ash, 22.7% wet gluten and 407-s falling Number was procured from the AceeArd Co., Khorasan, Iran. Dried active yeast was obtained from Fariman Co., Khorasan, Iran. All of the other chemicals, reagents and solvents used were of analytical grade type and were obtained from reputed companies.

B. Packaging materials

The films were used to pack the Barbari bread were (i) an OPP film (33 µm) with permeability of O2 and water vapor of 186.19 ml/ m2.24h and 4.02 g/m2.24h respectively, (As the control); (ii) a laminated PET-Al-LLDPE (12-7-65 µm) with permeability of O2 and water vapor of 0.04 ml/ m2.24h and 0.488 g/m2.24h) respectively, obtained from Plastic Machine Alvaan Co., Tehran, Iran and (iii) vacuum bags (PET-PET-LLDPE) (12-12-65 µm) with permeability of O_2 and water vapor of 0 ml/ m2.24h and 2.30 g/m2.24h respectively, obtained from Tahavol Kala Novin Co., Tehran, Iran. These films will be subsequently referred as film 1, film 2, and film 3 respectively.

C. Headspace gases

For the MAP of the Barbari bread, the headspace gases used were 70% CO_2 and 30% N_2, 50% CO_2 and50% N_2 obtained from the Khorakian oxygen Co., Khorasan, Iran, and air (as a control). The mixed gases had a purity of 99.9%. Nine different packaging combinations were investigated by combining the described packaging materials; for the sake of simplicity they will be referred to as: A1 = Film 1 + air; A2 = Film 1 + 50% CO_2 and 50% N_2; A3 = Film 1 +70% CO_2 and 30% N_2; B1 = Film 2+ air; B2 = Film 2 + 50% CO_2 and 50% N_2; B3 = Film 2 + 70% CO_2 and 30% N_2; C1 = Film 3 + air ; C2 = Film 3 + 50% CO_2 and 50% N_2 ; C3 = Film 3 + 70% CO_2 and 30% N_2. A1 was considered as control.

D. Bread making and packaging

The flat bread investigated in this study was ''Barbari'', which is one of the most consumed flat breads in Iran. The traditional formula used for this kind of bread, which was also used in these experiments, was: flour 100 parts; compressed yeast 2 parts; salt 2 parts; sugar 1 part; shortening (hydrogenated vegetable oil) 1 part; water (water absorption at 400 BU). Preparation of dough was similar to the technique described by [23]. A 200 g flour sample per loaf of bread was used in a straight dough preparation with optimum mixing time (TM electronic stand mixer, Hugel GmbH Neuss, Germany) and oxidation level. Sheeting of dough was carried out as described for the determination of baking quality of cookie flour using 6.3-mm gauge bars [24]. The procedure and conditions of dough preparation and baking were: (a) mix all ingredients for proper mixing time; (b) round and ferment on baking sheets for 60 min at 30°C and 75-85% R.h.; (c) punch and rest in fermentation cabinet for 20 min; (d) sheet, cut and proof; and (e) bake at 260°C for 13 min. In this study, samples were proofed for 30 min and baked for 13 min to obtain the proper thickness and acceptable color and texture. After proper initial cooling time, all Barbari bread samples were shifted from the Clean Room, (CVZ 2318, Beasat Ind Co., Qom, Iran.), to the packaging laboratory and each slice with area of 100 cm2 and 16 mm thickness, was placed in a bags made of film1, film2 and film3. Bread was packed using a vacuum packaging machine, (Boxer 42, Henkelman Ind Co., Netherland) programmed to form and injection of headspace gases in the packing bags.

E. Moisture content and water activity determination

A Moisture Analyser MX-50 model (A&D Co., Limited, Tokyo, Japan) was used to quantify the moisture content of the bread. Water activity (aw) was measured at 25°C with a water activity meter (Novasina ms1-a_w, Axair Ltd., Switzerland) after calibration with standard salt [25].

F. Hardness determination

The change in the texture of Barbari flat bread due to staling was measured using the penetration test. A QTS texture analyzer (CNS Farnell, Hertfordshire, UK) was used to measure the force required for penetration of a round-bottom (2.5 cm diameter x 1.8 cm height) probe at a velocity of 30 mm/min into the bread. The settings of the texture analyzer were: Trigger Value at 0.05 N and Target Value at 30 mm. Results are the average of three determinations [26].

G. Sensory evaluation

Sensory quality was evaluated by 10 trained panelists with proven skills according to [25]. From each sample, half of the bread slices were served on white, odourless, disposable plates. Samples were scored for appearance, odour, Taste, texture and overall quality using a scale from 0 (unfit) to 5 (excellent) [27]-[30]. Samples with scores of <2 were regarded as unacceptable for sale, and with scores of < 1.5 unacceptable for human consumption. Panelists were also asked to describe any defects noticed in sensory quality.

H. Microbial growth

Inspection for visible microbial growth on bread slices was done daily through the unopened packages. The microbial shelf-life was considered as the time period from packaging to the day of observation of microbial growth [2], [27]. The bread was considered unacceptable if the bread showed visible signs of mold. A conventional pour plate microbial count was not carried out for two reasons: firstly, during the homogenization phase, the mycelia always broke up, giving rise to a very large number of colony forming units (cfu) [2], [30]. Secondly, since the bread slice was not uniformly contaminated, estimation of the average microbial count would not be representative of the local microbial population. In fact, the method used in the present study to determine microbial spoilage of the bread is very close to the consumer's perception of bread quality [2].

I. Statistical analysis

In order to assess significant differences among samples, a completely randomized design was performed using the MSTATC program (ver 1.41). Duncan's new multiple range test was used to describe means with 95% confidence. Correlation coefficients (r) were computed using MINITAB (version 13.20, 2000) software.

III. Results and Discussion

A. Effect of modified atmosphere on Barbari bread quality

The water activity of bread slices packed in both air and CO_2, was 0.95 and did not significantly change during storage. Due to this minor change in aw it was decided not to use aw for the study of bread staling. References [3], [12] also reported small changes in a_w of bread crumb during storage. Hardness values for Barbari bread slices stored in air and CO_2/N_2 gas mixture for 21 days are given in table 1. There was an increase in the force required to compress the CO_2-packed bread with storage time, compared to air-packed bread at the end of the storage period. These results are in disagreement with those of [7], [31] who have showed lower compression forces for bread flushed with CO_2, indicating that CO_2 delays bread staling but we observed that CO_2 increased bread staling significantly. Also, the range of forces required to compress air- packed bread remained almost constant from the 7th storage day. References [7], [31] also reported this result. There were significant correlation coefficients between headspace CO_2 concentrations and hardness. Table 2 shows positive correlations among headspace CO_2 concentrations and hardness of Barbari bread.

TABLE I
EFFECT OF THE MODIFIED ATMOSPHERE PACKAGING AND DIFFERENT PACKAGING ON THE HARDNESS OF THE BARBARI BREAD

Treatment	Time(days)				
	0	3	7	14	21
A1	2.132	2.935[bc]	2.253[b]	3.273[b]	3.754[bcd]
A2	2.148	2.918[bc]	5.27[a]	5.703[a]	6.263[a]
A3	2.130	3.724[a]	6.277[a]	6.97[a]	6.973[a]
B1	2.144	2.610[c]	2.743[b]	3.183[b]	3.417[cd]
B2	2.146	2.756[c]	3.173[b]	3.49[b]	4.655[b]
B3	2.135	3.372[ab]	3.493[b]	4.08[b]	4.315[bc]
C1	2.134	2.435[c]	2.603[b]	2.633[b]	3.133[d]
C2	2.140	3.134[bc]	3.473[b]	3.677[b]	4.437[b]
C3	2.143	2.558[c]	3.043[b]	3.397[b]	3.265[d]

Values are the average of three replicates samples; different letters in the same column indicate significant differences, ($p \leq 0:05$).

Utilization of modified atmosphere packaging had no significant effect on the crumb moisture loss and moisture content during storage. Table 3 shows correlation coefficients of moisture content, crumb moisture and hardness values of Barbari bread, which was stored at modified atmosphere packaging. The hardness values of the Barbari bread crumbs showed a significant negative correlation with moisture content and crumb moisture of bread. Similar results were reported by [13]. Rate of firming has an inverse relationship to crumb moisture content [14]. Reference [32] proposed that water acts as a plasticizer in the bread. The decrease in the moisture content favors the formation of hydrogen bonds among the starch polymers or between the starch and the proteins yielding greater hardness. Also the inverse relationship between the hardness and the moisture content has been previously reported [13], [14], [33], [34]. No sign of microbial activity was observed after 21 days at 25 °C for the loaves packed in 70% CO_2 and 30% N_2 and 50% CO_2 and 50% N_2. For breads stored in atmospheric air, microbial activity was observed after 8 days. References [3], [6] also reported the same observations.

TABLE II
CORRELATION COEFFICIENTS BETWEEN HEADSPACE CO_2 CONCENTRATIONS AND HARDNESS

	hardness		
Treatment	A	B	C
r	0.997	0.997	0.599

Correlation significant at $P < 0.05$.

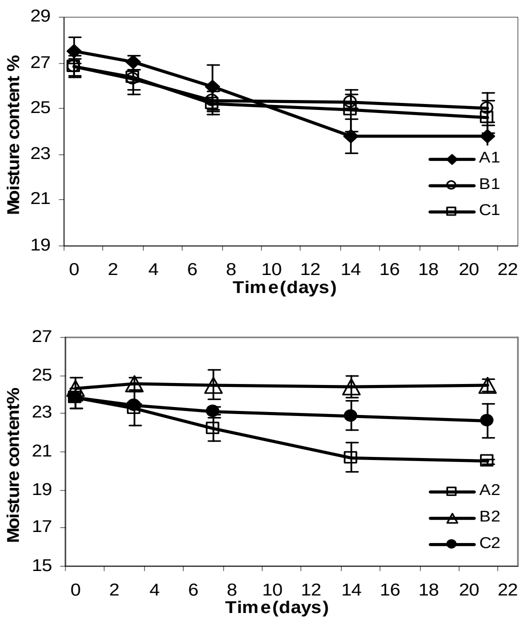
TABLE III
CORRELATION COEFFICIENTS BETWEEN MOISTURE CONTENT, CRUMB MOISTURE AND HARDNESS

		r	
		moisture content	crumb moisture
Hardness (N)	A1	-0.822	-0.96
	A2	-0.948	-0.854
	A3	-0.957	-0.95
	B1	-0.933	-0.912
	B2	0.338	-0.95
	B3	-0.93	-0.96
	C1	-0.891	-0.896
	C2	-0.987	-0.919
	C3	-0.878	-0.974

Correlation significant at P <0.05.

B. Effect of different packaging on Barbari bread quality

The air packed breads in film 3 have the lowest hardness from 21th days of storage period in contrast the breads package in OPP bags (film 1) have most hardness from 21th days of storage period. Figure 1 shows the changes in the amounts of moisture content for loaves stored in different packaging. The lowest decrease of moisture content of Barbari bread was for high barrier bags (film 2) and vacuum bags (film 3).There are significant differences between moisture content of bread stored in film 1 with film 3 (A & B) from 21th days of storage period.



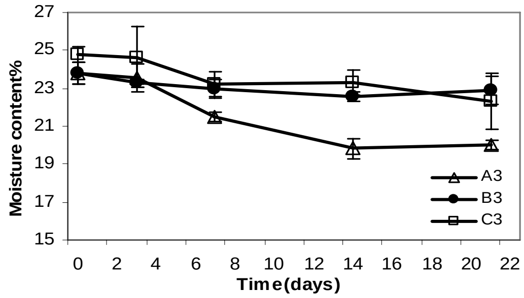


Fig. 1 Moisture content of Barbari bread fortified with soy flour stored in different packaging at modified atmosphere

Figure 2 shows the changes in the amounts of crumb moisture for loaves stored in different packaging. The moisture of the bread crumb stored in OPP bags have the highest decrease during storage period inverse the bread stored in vacuum bags and high barrier bags have a lower decrease in crumb moisture during 21 days storage time.

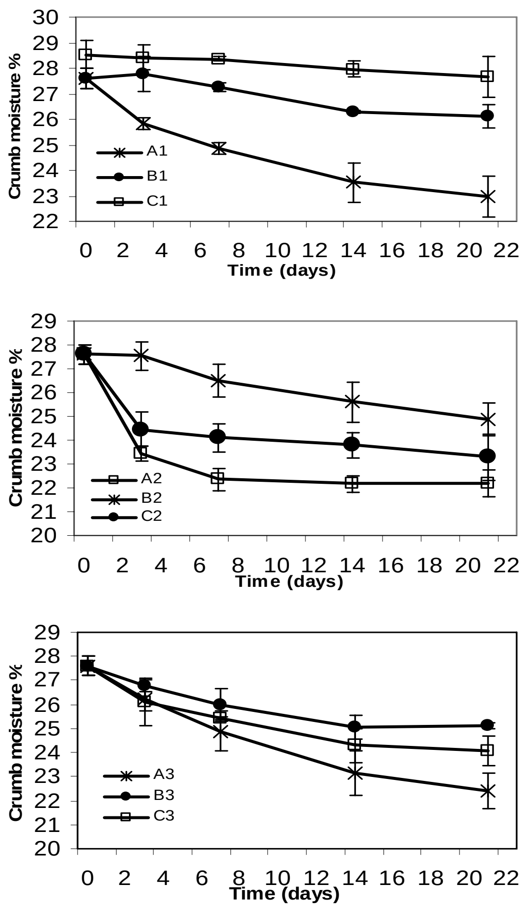


Fig. 2 Crumb moisture of Barbari bread fortified with soy flour stored in different packaging at modified atmosphere

C. Effect of the modified atmosphere packaging and different packaging on the sensory quality of the Barbari bread

The scores for quality characteristics of Barbari bread stored in different packaging at modified atmosphere were shown in table 4. The sensory evaluation was carried out in artificial light and the temperature of packed product was similar to ambient temperature. Parameters with the greatest influence on bread quality and acceptance by consumers particularly are appearance, taste, odor and texture; therefore, sensory quality of stored products and overall quality was the main subject of this investigation. This method described by [27]. After three weeks, however, differences in sensory attributes and microbial growth were more significant with regard to O_2 concentration in gas mixture composition in packaging. The quality of product packed under MAP is also dependent on gas composition. The kind of packaging is also a very important element in shelf life. It was evident that all sensory attributes received scores higher than 3 in 1 and 2 treatments. High CO_2 levels may, however, cause changes in taste of products. Sour or acidy taste observed in samples packaged in high level CO_2 by panelists.

TABLE IV
EFFECT OF THE MODIFIED ATMOSPHERE PACKAGING AND DIFFERENT PACKAGING ON THE HARDNESS OF THE BARBARI BREAD

Treatment	Characteristics				
	appearance	odour	Taste	texture	overall quality
A1	3.40[a]	4.20[a]	4.20[a]	3.80[a]	3.80[a]
A2	3.40[a]	3.80[a]	3.80[a]	3.20[a]	3.20[a]
A3	3.60[a]	3.00[b]	3.20[b]	2.80[b]	2.80[b]
B1	3.80[a]	4.20[a]	4.20[a]	3.80[a]	3.80[a]
B2	3.80[a]	4.20[a]	4.20[a]	3.60[a]	3.60[a]
B3	3.20[a]	3.20[b]	3.40[b]	2.40[b]	2.40[b]
C1	3.40[a]	4.00[a]	4.00[a]	3.40[a]	3.40[a]
C2	3.60[a]	4.00[a]	4.00[a]	3.60[a]	3.60[a]
C3	3.80[a]	3.20[b]	3.10[b]	2.80[a]	2.60[b]

Values are the average of ten replicates samples; different letters in the same column indicate significant differences, ($p \leq 0:05$); All scores were from 0 to 5, with 5 being the highest value.

Headspace gas composition data were correlated with sensory parameters. There were significant negative correlation coefficients between level of CO_2 gas and sensory parameters of the Barbari breads which stored at modified atmosphere. The correlation coefficients between the level of CO_2 gas and sensory parameters are shown in Table 5.

TABLE V
CORRELATION COEFFICIENTS BETWEEN MOISTURE CONTENT, CRUMB MOISTURE AND HARDNESS

Characteristics	CO_2 concentration			hardness		
	A	B	C	A	B	C
appearance	0.721	-0.721	0.24	-	-	-
odour	-0.908	-0.839	-0.721	-	-	-
taste	-0.937	-0.721	-0.721	-	-	-
texture	-0.992	-0.806	-0.533	-0.999	-0.852	0.359
overall quality	-0.992	-0.806	-0.577	-0.999	-0.852	0.309

Correlation significant at $P < 0.05$.

The correlation coefficients between the hardness and sensory parameters are shown in Table 5. A high negative correlation was found between hardness and sensory parameters in A and B bags. Similar results were reported by [21]. Table 5 also indicates a low correlation coefficient between hardness and sensory parameters in C bags. It seems that the decrease in the hardness of breads stored in C bags may mainly due to increased barrier properties of the C bags from A and B bags, which caused, the moisture remains better in the bags, and thus bread remains soft. However shelf life of Barbari bread significantly increased when the CO_2 concentration was increasing.

D. Microbial growth

Use In samples containing CO_2 gas, no microbial growth was observed over the storage period (21 days) in contrast control samples microbial growth was observed 4 days after packaging.

IV. CONCLUSIONS

Our data confirm that carbon dioxide is an effective preservative for bakery products [5], [6], and indicate that it increase the firming of Barbari bread. From the data reported, it can be concluded that (i) the microbial shelf life of the Barbari bread was extended by at least 21 days or more as a result of MAP; (ii) this extension of microbial shelf life could be obtained without the addition of calcium propionate to the dough generally used to make the Barbari bread; (iii) the best conditions for decrease of the hardness of the Barbari bread was obtained by the use of film 2 and 3 with atmospheric air; (iv) with the increasing of CO_2 in headspace , hardness will increase significantly. This effect is possibly due to matter of when a package is flushed with a mixture of gases including CO_2, the CO_2 dissolves partly in the product and creates a partial vacuum and package volume decreased during the first week of storage and compressed the breads [35], [36].

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