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Comparison of methods for the assessment of the extent of staling in bread

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Most of the physico-chemical methods used for indirect measurement of staling in western pan bread have been used for measuring the extent of staling in arabic bread. The water activity and alkaline water retention capacity values decreased significantly with the ageing of bread samples. The amount of soluble starch and amylose contents also decreased significantly as the bread aged during storage. In spite of their limitations, sensory analysis parameters were found to follow the staling of white as well as extra bran arabic bread more closely than any other single method. Instron puncture force measurements correlated well with other chemical methods and sensory analysis parameters in white arabic bread, but did not provide significant correlations for extra bran Arabic bread. Based on the data presented for the different physical, chemical and sensory methods investigated in this study, the alkaline water retention capacity produced the best correlation with most of these parameters. This test is, therefore, recommended as an appropriate objective method for assessing the extent of staling of arabic bread.

INTRODUCTION

Bread is the main staple food item in the Middle Eastern diet. Although bread consumption varies from one country to another and among individuals in the same country, its importance in meeting nutritional needs has been assessed. In Kuwait, the estimated daily per capita bread consumption is 277 g, which provides about 30% of the total recommended daily energy requirements. Arabic bread is the type most often consumed (Eid & Bourisly, 1986). The Kuwait flour mills and bakeries produce more than 2 million loaves/day in eight automatic bakeries distributed in different locations, accounting for more than 65% of the total arabic bread production in the country. White arabic bread is being produced from straight-run wheat flour, salt (0.75–1.5%), yeast (0.5–1%) and water. For extra bran arabic bread, 10% of fine wheat bran is added to the whole wheat flour (97% extraction), yeast, salt and water. The arabic bread dough is stiff with a farinograph dough consistency of 650 BU. The automation of the processing operation and the organizational set-up of the company has given it the advantage of enforcing better quality control measures on the consistency of the final product. Less than 1 day shelf-life of white arabic bread and the 6 h of extra bran arabic bread presents a major problem in Kuwait and can be costly to the producer, distributor, consumer and the country in general. The short shelf-life of arabic bread, which is mainly due to staling, is a serious problem.

Arabic bread is a double-layered flat bread that is generally made from flour, active dry yeast (starter), salt and water. Water absorption is variable and significantly affects the physical characteristics and flavor of the bread (Moussa *et al.*, 1979). A flour of 70% extraction is popular for this type of bread, although flours with higher extraction rates are also being used. The processing steps involved in arabic bread making have been described by Qarooni (1990). The inclusion of some additives like ascorbic acid, sodium stearoyl-2-lactylate and shortening are reported to improve quality of bread (Qarooni *et al.*, 1988; Qarooni, 1994).

Staling of bread is a highly complex phenomenon that is not yet fully understood. A number of tests, e.g. changes in crumbliness, water-absorbing capacity, crumb compressibility, amount of soluble starch, amylose or amylopectin extracted, X-ray diffraction patterns and thermal properties, have been used as direct or indirect indices of staling (Kulp & Ponte, 1981; Maga, 1975; Mahmoud & Abou-Arab, 1989; Faridi & Rubenthaler, 1984). However, it is accepted that the rates of change in these properties differ and none as a single parameter provide a complete description of the degree of bread staling perceived by the consumer. Considering the limitations of these methods, a number of techniques were studied to select an appropriate method for assessing the staling of arabic bread. Literature on the staling of arabic bread and on the methods for the measurements of the extent of staling are scarce.

The purpose of this study was to investigate the application of methods used in the measurement of the staling of western pan bread, for the evaluation of extent of staling in arabic bread.

MATERIALS AND METHODS

Materials

Arabic white bread (white khaboos) and extra bran arabic bread (extra bran khaboos) loaves commercially prepared and wrapped in plastic bags, as conventionally done, were obtained immediately after baking from the Kuwait flour mills and bakeries, Shuwaikh. The khaboos was immediately frozen using liquid nitrogen and was kept frozen for transport to the laboratory. At the same time, additional packets of extra bran and white khaboos (about 100 breads) were also collected from the bakery. The samples were then transported to the laboratory for storage studies. These trials were repeated three times during the duration of the study.

Storage studies

The extra bran and white khaboos samples packaged in polyethylene bags and sealed at the bakery were marked for 0, 1, 2, 3 and 4 days storage at room temperature. The temperature in the laboratory during the entire 4 day storage period was $22 \pm 1\,^{\circ}C$. These khaboos samples were analyzed daily for various physicochemical and sensory features.

Chemical analysis

On each day of storage, the khaboos samples were analyzed for moisture content, water activity, Instron texture and sensory quality. To determine moisture content, 2 g of khaboos were weighed, in triplicate, in aluminum dishes and dried to a constant weight in a vacuum oven at 70 °C (AOAC, 1990). To measure water activity, 50 g of khaboos was quickly chopped into small pieces and taken into a conical flask and the water activity was measured with a hand-held digital water activity probe (Vaisala Model HMI 31, Finland).

A representative sample of each storage treatment group was freeze-dried. The freeze-dried khaboos samples were powdered in a Hagberg falling number mill to pass through a 100 mesh sieve and stored in air tight containers in a refrigerator for further chemical analysis. The moisture content was determined by the vacuum oven method (AOAC, 1990). The alkaline water retention capacity (AWRC) of the freeze-dried bread samples was measured by the method reported by Yamazaki (1953) as modified by Kitterman & Rubenthaler (1971).

The water-soluble material was extracted from the freeze-dried khaboos samples (5 g) with 30 ml of distilled water by shaking for 20 min (Morad & D'Appolonia, 1980). The slurry was centrifuged (2000 *g* for 5 min) and the supernatant was filtered through Whatman no. 1 filter paper. The procedure was repeated twice and the three supernatents were combined and freeze-dried. For the isolation of soluble starch, Schoch and French's (Schoch & French, 1947) procedure was modified and used. The total water solubles extracted (combined supernatents) were made up to 100 ml. From this, 5 ml in duplicate was taken for the estimation of total water solubles by the vacuum oven drying method; 10 ml in duplicate was taken for the estimation of amylose content by the procedure reported by Williams *et al.* (1970). The amylopectin content was estimated by subtracting the amount of amylose from the total amount of soluble starch. To the remaining supernatant, three volumes of methanol were added, the mixture was heated in a boiling water bath for 1 h and then left overnight in a refrigerator. The next morning, the flocculated starch was collected by centrifugation (16 300 *g* for 20 min), dispersed in about 30 ml of distilled water and freeze-dried. The amount of total soluble starch was then calculated.

All the results of these chemical analyses are expressed on dry basis. The reagents used in this study were of analytical grade.

Objective texture measurements

An Instron universal testing machine (Instron Eng. Corp., Canton, Ma) was used to measure the objective texture (degree of firming) of the bread during storage. Two representative khaboos samples were taken for instrumental texture measurement using series IX automated materials testing system 1.16 with the 4500 series interface. On each khaboos, 12 measurements were taken at different points about 1 in apart. The force, in newtons, required for the 4 mm diameter probe to puncture through the khaboos was recorded. These readings were taken an inch away from the periphery to minimize dry edge effects. The machine's parameters were: crosshead speed, 50 mm/min; sample rate, 5-points/s; probe diameter, 4 mm; humidity, 50%; temperature, 25 °C. After discarding the highest and lowest readings, the mean values and their standard deviations were recorded.

Sensory analysis

On each day of storage, representative samples of khaboos were analyzed on a five point hedonic scale for texture, flavour and overall acceptability, using a semi-trained panel of Kuwait Institute for Scientific Research employees as judges. For the sensory analysis, a sample of fresh khaboos obtained daily from the bakery was provided to the panelists as control. The panelists were

Table 1. Moisture content, water activity and alkaline water retention capacity (mean ± S.D.) of arabic bread samples stored at room temperature

Type of arabic bread	Storage time	Moisture content[a] (%)	Water activity[b]	AWRC[c] (%)
Extra bran khaboos	0	28.26 ± 0.86	0.89 ± 0.004	346.54 ± 5.34
	1	28.49 ± 1.04	0.84 ± 0.001	243.14 ± 10.05
	2	29.25 ± 0.59	0.82 ± 0.002	224.60 ± 11.16
	3	29.14 ± 0.47	0.82 ± 0.002	217.74 ± 9.96
	4	28.47 ± 0.88	0.80 ± 0.003	217.80 ± 2.94
White khaboos	0	28.54 ± 0.40	0.88 ± 0.002	369.00 ± 5.66
	1	28.95 ± 0.28	0.85 ± 0.001	252.88 ± 11.78
	2	28.45 ± 0.18	0.84 ± 0.003	228.80 ± 10.45
	3	28.39 ± 0.27	0.84 ± 0.004	218.20 ± 9.55
	4	28.79 ± 0.06	0.83 ± 0.003	209.04 ± 1.87

[a]No significant difference ($P = 0.05$) was observed between the moisture contents of the extra bran and white khaboos or between storage periods.
[b]Significant difference ($P = 0.05$) was observed between the water activity of the extra bran and white khaboos over storage periods.
[c]Significant difference ($P = 0.05$) was observed between the awrc of the extra bran and white khaboos over storage periods.

provided with test khaboos as well as fresh khaboos and were asked to assign scores on a five point scale for texture, flavour and overall acceptability.

Statistical analyses

The experimental data obtained were analyzed statistically for variance (Sokal & Rohlf, 1981) and inference reported at the appropriate places. For the results, the mean values and standard deviations were calculated.

RESULTS AND DISCUSSION

The white flour and whole wheat flour used by the Kuwait flour mills and bakeries for the production of white khaboos and extra bran khaboos were analyzed for moisture, protein, ash and fat contents by standard AACC, 1990 methods. The white flour had protein, ash and fat contents of 12.64, 0.69 and 1.34%, respectively. The whole wheat flour had higher protein (14.21%), ash (1.32%) and fat (1.85%) contents.

Storage studies

During the storage studies, the white khaboos and extra bran khaboos samples were analyzed for moisture content, water activity and AWRC (Table 1). No significant differences between the moisture contents of white khaboos (28.54%) or extra bran khaboos (28.26%) were detected. The moisture contents of these bread samples did not vary significantly during storage periods. In the present study, average moisture content observed for khaboos was lower than the reported value of 38% for white pan bread (Kulp & Ponte, 1981). The arabic bread, being thinner and having a greater surface area, would lose greater amounts of moisture during baking as well as during the cooling operation in the bakery, thus resulting in lower moisture contents. As the khaboos, after cooling, was packaged in good moisture barrier polyethylene, it lost practically no moisture during the 4 day storage period. This indicates that staling of arabic bread is not probably only due to the loss of moisture by the drying-out process. Even though the moisture content did not change significantly during storage, the arabic bread became stale (as shown by the sensory analysis results). However, a significant decrease in the water activity values was observed during this period. The free water present in the freshly baked khaboos which gave higher water activity values, was probably bound to the hydrophilic constituents (e.g. starch) of the khaboos during storage.

The AWRC test has been used for the evaluation of cookie baking potential of soft wheat flours (Yamazaki, 1953). This test has even been scaled down to micro proportions for assessing the quality of early generation wheat selections (Kitterman & Rubenthaler, 1971). The AWRC test was applied to study the extent of staling in arabic bread. The AWRC showed considerable and significant variations as the khaboos samples aged during the storage period. The AWRC values for the zero day extra bran and white khaboos samples were 346.54 and 369.0%, which decreased at the end of the 4 day storage period to 217.80 and 209.04%, respectively. Within the extra bran and white khaboos sample groups, the AWRC values did not vary significantly. Arabic bread samples initially had higher imbibitional properties which decreased significantly during storage. As the amylose and amylopectin fractions get crystallized during, their water binding capacity comes down. The AWRC, therefore, gave a very high positive correlation with amylose content.

Total water-solubles

The effect of aging on the total amounts of water-solubles extracted from khaboos samples at different storage times is presented in Table 2. The amount of soluble material extracted from extra bran khaboos was significantly higher (12.65%) than that extracted from the

Table 2. Effect of storage time on total solubles, soluble starch, amylose and amylopectin contents (mean ± S.D.) of arabic bread samples stored at room temperature

Type of bread	Storage time (d)	Total water solubles[a] (%)	Soluble starch[b] (%)	Amylose[c] (%)	Amylopectin[d] (%)
Extra khaboos	0	12.65 ± 0.38	2.35 ± 0.03	0.45 ± 0.009	1.90 ± 0.019
	1	12.54 ± 0.23	1.85 ± 0.09	0.23 ± 0.008	1.62 ± 0.074
	2	12.37 ± 0.20	1.63 ± 0.01	0.18 ± 0.009	1.45 ± 0.014
	3	12.29 ± 0.26	1.59 ± 0.01	0.17 ± 0.002	1.42 ± 0.011
	4	12.26 ± 0.07	1.58 ± 0.02	0.16 ± 0.006	1.41 ± 0.041
White khaboos	0	10.53 ± 0.06	2.17 ± 0.13	0.98 ± 0.001	1.19 ± 0.109
	1	10.50 ± 0.02	1.67 ± 0.08	0.59 ± 0.004	1.08 ± 0.063
	2	10.45 ± 0.28	1.56 ± 0.11	0.48 ± 0.004	1.07 ± 0.084
	3	10.46 ± 0.17	1.49 ± 0.14	0.45 ± 0.003	1.04 ± 0.118
	4	10.33 ± 0.16	1.48 ± 0.18	0.39 ± 0.004	1.09 ± 0.055

[a]Significant difference ($P = 0.05$) was observed between the total water solubles extracted from the extra bran and white khaboos.
[b]Significant difference ($P = 0.05$) was observed between the total soluble starch extracted from the extra bran and white khaboos over the storage periods.
[c]Significant difference ($P = 0.05$) was observed between the amylose content of the water soluble extracts obtained from the extra bran or white khaboos as well as between storage periods.
[d]Significant difference ($P = 0.05$) was observed between the amylopectin content of the water soluble extracts obtained from the extra bran khaboos during the storage periods as well as between the extra bran and white khaboos.

white khaboos (10.53%). This difference between the two types of khaboos was maintained to the end of the storage period and may be due to the inclusion of more nitrogenous compounds and glycoproteins from the whole wheat flour used in making extra bran khaboos. The amount of water-solubles extracted is higher for white khaboos (10.33%) than for western pan bread (6.7% after 96 h of storage) as reported by Morad & D'Appolonia (1980). The higher amounts of water-solubles extracted from white khaboos could be due to the difference in the baking formulae as well as due to the shorter bulk fermentation time employed in khaboos making.

Soluble starch, amylose and amylopectin

Table 2 indicates that the amount of soluble starch extracted decreased as the khaboos aged, with the greatest decrease occurring during the first 2 days, after which it levelled off. The fresh samples of extra bran as well as white khaboos had soluble starch contents of 2.35 and 2.17%, respectively, which decreased to corresponding levels of 1.58 and 1.48% at the end of the 4 days storage period. Significant differences were found in the amounts of extracted soluble starch with the ageing of both the white and extra bran khaboos. The levels of soluble starch obtained in the khaboos samples during storage are closer to the values of soluble starch reported for the continuous baking method than for the straight dough method used for western pan bread (Morad & D'Appolonia, 1980). This may be due to a shorter bulk fermentation period being used for khaboos making. The data presented in Table 2 shows that the amount of soluble starch extracted from the khaboos samples decreased during storage as the staling process progressed. A similar decrease in the amount of soluble starch has also been observed during the staling of white pan bread (Schoch & French, 1947).

The changes in the amylose and amylopectin contents of soluble starch extracted after different storage times from white as well as extra bran khaboos are also presented in Table 2. A significant difference was observed in the amylose and amylopectin contents in both types of khaboos samples as well as during their storage. The amount of amylose, although small in comparison with the amount of amylopectin in the extracted soluble starch, decreased rapidly during the first day of storage, after which it levelled off. The amylose content in soluble starch extracted from fresh extra bran khaboos was 0.45%, which decreased to 0.16% after 4 days of storage, whereas in case of fresh white khaboos, these values were 0.98 and 0.39%, respectively. A decrease in the amylopectin content in the extracted soluble starch was also observed during the storage period. The amylopectin contents decreased in extra bran khaboos from 1.90 to 1.19% and in white khaboos from 1.19 to 1.09% after 4 days of storage. This decrease in amylopectin contents during the ageing of pan bread has been suggested as one of the probable causes of staleness (De Stefanis *et al.*, 1977). The decrease in amylose and amylopectin contents in the soluble starch extracted from khaboos during storage may be due to retrogradation/crystallization, which would reduce their solubility.

Objective texture measurements

The white as well as the extra bran khaboos samples stored for 4 days were evaluated at intervals for objective texture by measuring peak force (newton) using the Instron universal testing machine (Table 3). The peak force required to puncture a 4 mm hole in the khaboos sample was used as an indication of the sum total of various textural attributes such as toughness and crumbliness. The peak force required in case of white khaboos increased from 5.527 for zero days to 7.421

Table 3. Effect of aging on the instrumental (instron) texture peak force values of arabic bread (khaboos) during storage at room temperature

Storage time (d)	Peak force (N)	
	White khaboos mean ± S.D.	Extra bran khaboos mean ± S.D.
0	5.527 ± 1.830	7.142 ± 1.097
1	5.944 ± 1.019	6.173 ± 0.678
2	7.421 ± 0.871	4.307 ± 0.773
3	7.335 ± 1.582	6.689 ± 0.666
4	7.185 ± 1.061	7.061 ± 0.659

The F-values (df = 4,95) obtained for the white khaboos and extra bran khaboos were 8.85 and 43.2, respectively.

Table 4. Sensory analysis scores (mean ± S.D.) of arabic bread (khaboos) during storage at room temperature

Storage time (d)	Texture		Flavour		Overall acceptability	
	White bread	Extra bran	White bread	Extra bran	White bread	Extra bran
0	3.89 ± 1.05	4.22 ± 0.83	4.11 ± 1.05	4.22 ± 0.83	4.22 ± 0.67	4.33 ± 0.71
1	3.78 ± 0.67	3.22 ± 1.30	3.78 ± 0.67	3.33 ± 1.12	3.78 ± 0.67	3.33 ± 1.12
2	2.88 ± 1.05	2.89 ± 0.60	3.22 ± 0.97	3.11 ± 0.78	3.33 ± 0.87	3.22 ± 0.67
3	3.11 ± 0.93	2.56 ± 0.88	3.00 ± 0.87	2.67 ± 0.71	3.00 ± 0.87	2.78 ± 0.83
4	2.78 ± 0.97	2.44 ± 0.73	3.00 ± 0.87	2.33 ± 0.87	3.00 ± 0.87	2.33 ± 0.87
F-value (df = 4,40)	2.64	5.66	2.81	6.16	4.02	6.90

after 2 days, but it then levelled off. The peak force required to puncture extra bran khaboos ranged from 4.307 to 7.142.

The extra bran khaboos behavior in the Instron puncture test was quite different than the white khaboos. The peak force decreased from zero days (7.142) to the second day (4.307), but then it increased until the fourth day (7.061). After the second day of storage, the extra bran khaboos was observed to crumble easily, but it became harder as more time lapsed. One possible explanation may be the typical behaviour of bran particles present in khaboos. The wheat bran in freshly baked khaboos may be more hydrated, which makes it tough, thus increasing the force required to puncture the khaboos. During the ageing of the bread, water may be transferred from the bran as well as from the gluten to a more hydrophilic component. i.e., gelatinized starch (Breaden & Wilhoft, 1971) This could lead to shrinking of the gluten strands, resulting in increased crumbliness, thus requiring less force to puncture the khaboos. At the end of 4 days of storage, the bread's structure may start to harden, again requiring a greater puncture force.

Sensory analysis

The white as well as the extra bran khaboos samples were evaluated during storage period for their sensory quality in terms of texture, flavour and overall acceptability on a five-point hedonic scale by a semi-trained panel and the results are presented in Table 4. The fresh white khaboos obtained a texture score of 3.89, which decreased significantly to 2.78 after 4 days of storage. Comparatively, the extra bran khaboos initially received a score of 4.22, which decreased significantly to 2.44 during the 4 days of storage. As can be seen from the statistical analysis, the sensory texture scores showed a significant decrease in both types of khaboos during the storage period.

The flavour scores for fresh white as well as the fresh extra bran khaboos were 4.11 and 4.22, respectively and decreased at the end of the 4 day storage period to corresponding values of 3.00 and 2.33. The fresh white khaboos obtained an initial overall acceptability score of 4.22, which decreased significantly at the end of the 4 day storage to 3.00; the fresh extra bran khaboos obtained an initial overall acceptability score of 4.33, which decreased significantly to 2.33 at the end of the storage period. The decrease in the khaboos' flavour and overall acceptability scores during the storage period was statistically significant. The sensory analysis scores may, therefore, indicate quite closely the progress of khaboos staling under these storage conditions.

Correlation coefficients between parameters

During this study, a number of physical, chemical and sensory parameters were used to assess the extent of staling in arabic bread (white khaboos and extra bran khaboos). The correlation coefficients between some of the important parameters like alkaline water retention capacity, Instron puncture force, total soluble solids, soluble starch content, amylose content, water activity, sensory texture score and overall acceptability score for white khaboos and extra bran khaboos are presented in Tables 5 and 6, respectively. As can be seen from

Table 5. Correlation coefficients between different parameters employed for the estimation of staling of white bread khaboos

	Alkaline water retention capacity	Total soluble solids	Soluble starch content	Amylose content	Water activity (a_w)	Sensory texture score	Overall acceptibilty score
Puncture force (Instron) (N)	−0.85	−0.68	−0.86	−0.87	−0.87	−0.82	−0.98
AWRC	—	0.70	0.99	0.99	0.99	0.60	0.84
Total soluble solids	—	—	0.68	0.75	0.81	0.89	0.56
Soluble starch content	—	—	—	0.99	0.98	0.60	0.89
Amylose content	—	—	—	—	0.99	0.66	0.88
Water activity (a_w)	—	—	—	—	—	0.70	0.85
Sensory texture score	—	—	—	—	—	—	0.69

Table 6. Correlation coefficients between the parameters employed for the estimation of staling of extra bran khaboos

	Alkaline water retention capacity	Total soluble solids	Soluble starch content	Amylose content	Water activity (a_w)	Sensory texture score	Overall acceptibilty score
Puncture force (Instron) (N)	0.38	0.14	0.35	0.37	0.27	0.56	0.34
AWRC	—	0.86	0.99	0.99	0.96	0.82	0.87
Total soluble solids	—	—	0.93	0.88	0.94	0.87	0.93
Soluble starch content	—	—	—	0.99	0.98	0.88	0.92e
Amylose content	—	—	—	—	0.97	0.83	0.88
Water activity (a_w)	—	—	—	—	—	0.81	0.85
Sensory texture score	—	—	—	—	—	—	0.96

Table 5, a strong negative correlation was observed between puncture force and AWRC, soluble starch, amylose, water activity and sensory parameters for white khaboos. The AWRC showed significant positive correlations with all other parameters such as total solids, soluble starch, amylose, water activity, Instron puncture force and sensory parameters. In the case of extra bran khaboos, however, a very poor correlation was observed between the Instron puncture force and most of the other parameters (Table 6). However, the other parameters such as AWRC, total solids, soluble starch, amylose content, water activity, sensory texture score and overall acceptability score, produced highly significant positive correlation among themselves. The AWRC produced a highly significant positive correlation with these parameters.

CONCLUSIONS

The results of this study show that khaboos deteriorates in sensory quality very fast. The khaboos loses its softness very fast, becomes stale, hard and crumbles on folding. It is clear that no single parameter can be taken as a sole criterion for assessing the progress of staling in arabic bread. Most of the chemical methods that have been used for indirect measurement of staling in western pan bread can also be used for arabic bread. In spite of their limitations, the sensory analysis parameters followed the staling of white as well as extra bran khaboos more closely than any other single method. Based on the data presented in this study, AWRC gave the best correlation with the greatest number of parameters. In addition to subjective method of sensory analysis, this test (AWRC) is, therefore, recommended as an appropriate objective method for assessing the extent of staling in arabic bread.

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