Food Chemistry 33 (1989) 281–289

Comparison of Methods to Determine the Extent of Staling in Egyptian-type Breads

R. M. Mahmoud & A. A. Abou-Arab

Food Science Department, Faculty of Agriculture, Ain Shams University, Shoubra El-Kheima, Cairo, Egypt

(Received 27 January 1988; revised version received and accepted 20 October 1988)

ABSTRACT

Staling rates of the most popular wheat bread-types (Balady, Shamy and Fino) were followed during 48 h of storage periods at room temperature by loss of moisture, total water solubles, swelling power, starch intrinsic viscosity and sensory evaluation freshness determinations. The rate of staling was higher in Balady bread than that of Fino and Shamy breads.

Comparisons were made between the different methods for determination of bread staling rate and correlation coefficients between the different methods and/or the organoleptic method calculated. The study established a correlation coefficient of 0·916 between organoleptic and swelling power values. Since swelling power is a simple and rapid test, it is recommended for following staling of Egyptian types of bread.

INTRODUCTION

Bread staling is an extremely complex phenomenon and is difficult to define in straightforward terms. Broadly speaking, bread staling refers to all changes that occur in bread after baking (D'Appolonia & Morad, 1981). The increase in crumb firmness has probably been used mostly by investigators following bread staling (Prentice *et al.*, 1954; Zobel & Senti, 1959; Waldt & Mahoney, 1967; Dragsdorf & Varriano-Marston, 1980). Other changes, such as loss in flavour, decrease in water absorption capacity, amount of soluble starch, swelling power and decrease in intrinsic viscosity of starch

Food Chemistry 0308-8146/89/$03·50

have also been used (Morad & D'Appolonia, 1980; Fahmy & Mansour, 1982; Pisesookbunterng *et al.*, 1983; Faridi & Rubenthaler, 1984).

In Egypt, the most popular wheat bread is Balady, a flat, circular loaf composed of two layers. Flour extraction rate is high (82%) for Balady bread and lower (about 72%) in Shamy bread; another bread type in Egypt is called Fino. It is made from the lower extraction rate flour (72%) and looks like French bread.

The three types of Egyptian bread differ in shape, moisture content and/or flour extraction rate. Therefore the changes in moisture, flavour, water absorption, total water solubles and starch viscosity during staling may be different.

This work was designed to compare different methods used in the determination of the extent of staling in Egyptian-type breads. Multiple correlations were used to evaluate the significance of each parameter in the determination of the extent of staling of Egyptian-type breads.

MATERIALS AND METHODS

Fresh Egyptian Balady, Shamy and Fino breads were obtained from local bakeries. The loaves were allowed to cool at room temperature for 2 h before being packed in polyethylene bags and stored at room temperature. Samples were taken daily for evaluation.

Moisture content was determined according to AACC method 44-15A (1976). For total water-soluble material determinations, a sample (5 g) of bread was extracted with distilled water (30 ml) by agitating the mixture on a wrist-action shaker for 20 min. The slurry was centrifuged at 2000*g* for 5 min, and the supernatant filtered. The procedure was repeated twice on the residue, and the combined supernatants were dried (Morad & D'Appolonia, 1980). Swelling power was determined according to AACC method 85·5b (1958).

Relative, specific, reduced and instrinsic viscosities of starch extracted from different types of bread were determined according to the method of Leach (1963) using a Cannon-Fenske capillary viscometer at different concentrations of 0·1, 0·2, 0·3, 0·4 and 0·5% in 1 M KOH solution. Starch was washed from the breads by making a slurry of bread with excess distilled water, gently stirring with a magnetic stirrer for 30 min, and then passing the slurry through bolting cloth. The filtrate was centrifuged at 2000*g* for 10 min and the supernatant discarded. The starch sediment was resuspended in distilled water, centrifuged again, and finally air-dried (Varriano-Marston *et al.*, 1980).

Sensory evaluation of bread freshness was investigated by eleven trained panelists. They were asked to mark biting texture that best described their feeling on a sheet containing the following six categories: very fresh, fresh, slightly fresh, slightly stale, stale and very stale, the ratings were given numerical values with very fresh = 6, very stale = 1. The results were assessed by analysis of variance according to the procedure of Larmond (1970). Correlation coefficients were calculated using an IBM computer PC-XT.

RESULTS AND DISCUSSION

Bread baking necessarily results in the setting up of macroscopic moisture gradients throughout the load. The development of leatheriness and loss of crispness of the crust are largely caused by migration of moisture from the crumb to the crust region during storage (Bic & Geddes, 1949; Bradley & Thomson, 1950; Yasunaga *et al.*, 1968).

The moisture contents of fresh Balady, Shamy and Fino breads were found to be 37·8, 27·7 and 39·7%, respectively (Table 1). The different moisture contents in different types of fresh breads may be due to differences in the original dough moisture contents, since variable amounts of water are available to enable starch to gelatinize during baking. On the other hand, the

TABLE 1

Changes in Moisture, Total Water Solubles and Swelling Power of Egyptian-Type Bread during Storage at Room Temperature

Bread-type	*Moisture (%)*	*Total water solubles (%)*	*Swelling power*
Balady			
Fresh[a]	37·8 ± 0·14	9·6 ± 0·04	5·1 ± 0·08
24 h	31·8 ± 0·19	9·5 ± 0·04	3·6 ± 0·05
48 h	31·6 ± 0·17	7·8 ± 0·05	3·6 ± 0·07
Shamy			
Fresh[a]	27·7 ± 0·18	7·4 ± 0·03	5·1 ± 0·08
24 h	23·0 ± 0·15	7·0 ± 0·06	4·4 ± 0·09
48 h	23·2 ± 0·16	6·4 ± 0·05	3·9 ± 0·05
Fino			
Fresh[a]	39·7 ± 0·16	9·0 ± 0·04	5·0 ± 0·02
24 h	37·4 ± 0·18	8·8 ± 0·02	3·6 ± 0·09
48 h	37·0 ± 0·17	7·7 ± 0·01	3·4 ± 0·04

[a] 2 h after baking.

Data are presented as means ± standard deviation of four samples.

moisture content of fresh Shamy bread was lower than fresh Fino and Balady breads because of excessive moisture loss during and immediately after oven baking. Moreover, the higher degree of starch gelatinization also binds more water in Shamy bread than in Balady and Fino breads. The same findings were obtained by Faridi & Rubenthaler (1984).

The rates of loss in moisture content of Balady and Shamy breads after 48 h of storage at room temperature were about 16%. Meanwhile, such loss was only about 7% in Fino bread. The higher moisture loss rate in Balady and Shamy breads was probably due to the thin flat shape of these breads.

These trends suggested that the staling rate is faster in Shamy and Balady breads than in Fino bread. However, these results may have been due to moisture loss by evaporation and/or redistribution between crumb and crust. In addition, the increase in protein denaturation, which is not heat-reversible, may have contributed to decreasing the reversibility of crumb firmness during storage (Willhoft, 1873; Pisesookbunterng *et al.*, 1983).

Atia (1986) observed that Balady bread baked at higher temperatures and shorter times had been reported to be soft initially and remained softer during 48 h of storage. She also found that the maximum freshness of Balady bread thus produced was lost in the first 48 h of storage; i.e. Balady bread has a relatively short shelf life.

Data on the amount of total water solubles extracted from breads are presented in Table 1. The amount of soluble material extracted decreased as the storage period increased. The findings confirmed those of Morad & D'Appolonia (1980).

The amount of total water-soluble material decreased at a faster rate in Balady bread (19%) during 48 h of storage than Fino (15%) and Shamy (13%) breads.

Swelling power also decreased as the storage period increased, as shown in Table 1. The decrements of swelling power were found to be about 32, 29 and 24% in Fino, Balady and Shamy breads, respectively.

The results indicate that moisture content, total water solubles and swelling power all decreased as the storage period increased. The results agree with those obtained by Varriano-Marston *et al.* (1980) who reported that the degree of starch gelatinization and swelling power in baked foods paralleled moisture content; i.e. the higher the moisture content, the greater the starch swelling.

Intrinsic viscosity is essentially a measure of the internal friction or resistance for displacement of high polymeric molecules in solution. It can be obtained by three different methods of graphical analysis where, in each case, data are extrapolated to zero. The first is reduced viscosity (i.e. specific viscosity divided by starch concentration) versus concentration. The second is inherent viscosity (i.e. natural log of relative viscosity divided by starch

TABLE 2
Changes in Relative, Specific and Reduced Viscosities of Starch Extracted from Balady Bread Stored at Room Temperature for 24 and 48 h

Starch conc. (%)	*Relative viscosity* $\eta_r = \frac{t}{t_0}$			*Specific viscosity* $\eta_{sp} = \frac{t - t_0}{t_0}$			*Reduced viscosity* $\eta_{red} = \frac{\eta_{sp}}{c}$		
	Fresh	*24 h*	*48 h*	*Fresh*	*24 h*	*48 h*	*Fresh*	*24 h*	*48 h*
0·1	1·127	1·130	1·091	0·127	0·130	0·091	1·237	1·303	0·909
0·2	1·258	1·303	1·212	0·258	0·303	0·212	1·288	1·515	1·061
0·3	1·394	1·515	1·364	0·394	0·515	0·364	1·313	1·717	1·212
0·4	1·350	1·773	1·546	0·350	0·773	0·546	1·326	1·932	1·364
0·5	1·682	2·061	1·697	0·682	1·061	0·697	1·364	2·121	1·394

Where t = Flow time of solution.
t_0 = Flow time of 1N KOH.
c = Concentration.

concentration) versus concentration. The third is reduced viscosity versus specific viscosity (Leach, 1963).

Changes in relative, specific and reduced viscosities of starch extracted from Balady, Shamy and Fino breads are shown in Tables 2–4.

Changes in intrinsic viscosity of starch extracted from bread during storage are shown in Fig. 1. A sharp decrease occurred in the intrinsic viscosity of starches during the first 24 h of bread storage. The decrease in intrinsic viscosity was 6·5, 8·8 and 23·5% for Shamy, Balady and Fino bread-

TABLE 3
Changes in Relative, Specific and Reduced Viscosities of Starch Extracted from Shamy Bread Stored at Room Temperature for 24 and 48 h

Starch conc. (%)	*Relative viscosity* $\eta_r = \frac{t}{t_0}$			*Specific viscosity* $\eta_{sp} = \frac{t - t_o}{t_0}$			*Reduced viscosity* $\eta_{red} = \frac{\eta_{sp}}{c}$		
	Fresh	*24 h*	*48 h*	*Fresh*	*24 h*	*48 h*	*Fresh*	*24 h*	*48 h*
0·1	1·099	1·091	1·082	0·099	0·091	0·082	0·985	0·909	0·818
0·2	1·212	1·191	1·170	0·212	0·191	0·170	1·061	0·955	0·848
0·3	1·333	1·303	1·267	0·333	0·303	0·267	1·111	1·010	0·889
0·4	1·485	1·424	1·361	0·485	0·424	0·361	1·212	1·061	0·902
0·5	1·636	1·545	1·470	0·636	0·545	0·470	1·273	1·091	0·939

TABLE 4
Changes in Relative, Specific and Reduced Viscosities of Starch Extracted from Fino Bread Stored at Room Temperature for 24 and 48 h

Starch conc. (%)	*Relative viscosity* $\eta_r = \frac{t}{t_0}$			*Specific viscosity* $\eta_{sp} = \frac{t - t_0}{t_0}$			*Reduced viscosity* $\eta_{red} = \frac{\eta_{sp}}{c}$		
	Fresh	*24 h*	*48 h*	*Fresh*	*24 h*	*48 h*	*Fresh*	*24 h*	*48 h*
0·1	1·121	1·091	1·021	0·121	0·091	0·021	1·212	0·909	0·212
0·2	1·242	1·182	1·054	0·242	0·182	0·054	1·212	0·909	0·273
0·3	1·364	1·273	1·085	0·364	0·273	0·085	1·212	0·909	0·283
0·4	1·485	1·364	1·127	0·485	0·364	0·127	1·212	0·909	0·318
0·5	1·606	1·455	1·170	0·606	0·455	0·170	1·212	0·909	0·339

type respectively. A more pronounced decrease in starch intrinsic viscosity was observed after 48 h of bread storage (15·1, 38·4 and 82·4%, for Shamy, Balady and Fino bread-type, respectively) as shown in Table 5.

The extent of decrease in starch viscosity is paralleled to the original bread-type moisture contents (Table 1).

These decreases in viscosity may have been due to changes in conformation of starch molecules after baking. In native starch granules,

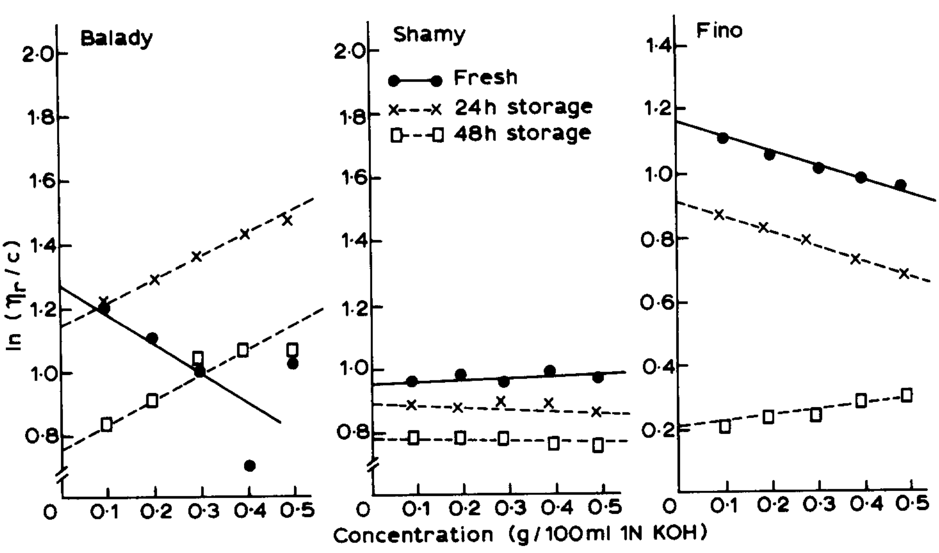

Fig. 1. Changes in intrinsic viscosity of starch extracted from Balady, Shamy and Fino bread during storage at room temperature.

TABLE 5
Percentage Decrease in Intrinsic Viscosity of Starch Extracted from Different Egyptian Type Breads during Storage at Room Temperature

Bread-type	*Decrease in intrinsic viscosity (%)*	
	24 h	*48 h*
Balady	8·8	38·4
Shamy	6·5	15·1
Fino	23·5	82·4

polymers assume a highly oriented, helical conformation. The internal friction during their flow through a capillary is relatively high giving a high intrinsic viscosity. Baking may cause some changes to the orientation of starch molecules to a coiled conformation with consequent lower intrinsic viscosity. The results obtained confirmed those obtained by Fahmy & Mansour (1982) who considered that, due to the association of the starch granules during staling, the intrinsic viscosity gradually decreased until it reached a maximum value in Balady bread stored for 72 h after staling. The decrement of intrinsic viscosity may also be due to a gradual change of molecules from coiled to fully extended structure through H-bond formation, which would also lead to a gradual decrease in intrinsic viscosity.

Means of sensory evaluation of bread freshness after 24 h and 48 h storage periods are summarized in Table 6. Both Fino and Shamy breads remained slightly fresh after 24 h storage. However, Balady bread became stale after 24 h storage. After 48 h of storage, Fino and Shamy breads became stale, and Balady-type very stale. Balady-type bread had a faster rate of staling which may have been due to the high extraction rate of flour used in Balady bread making. The extent of starch gelatinization of Balady bread was generally

TABLE 6
Means of Sensory Evaluation Data of Bread Freshness

Bread-type	*Storage time*		
	Fresh	*24 h*	*48 h*
Balady	5·00	1·91	1·64
Shamy	5·09	3·73	2·36
Fino	5·18	3·64	2·09

TABLE 7
Correlation Coefficient of Storage Time, Panel Freshness, Moisture Content, Total Water Solubles (TWS), Swelling Power (SP) and Intrinsic Viscosity (IV)

	Storage time	*Panel freshness*	*Moisture content*	*TWS*	*SP*	*IV*
Storage time						
Panel freshness	−0·913					
Moisture content	−0·308	0·244				
TWS	−0·531	0·244	0·778			
SP	−0·869	0·916	0·047	0·172		
IV	−0·768	0·530	0·567	0·853	0·501	

higher than that reported for Western pan bread (Varriano-Marston *et al.*, 1980), probably because of higher dough moisture during baking. The higher the degree of starch gelatinization and swelling, the greater the rate of staling.

To compare the different methods used for determination of staling rate of different types of bread, the correlation coefficients between storage time, panel freshness, moisture content, total water solubles, swelling power and intrinsic viscosity values were calculated. The data are presented in Table 7. The panel score, swelling power and starch intrinsic viscosity were found to be significantly correlated with the storage time of bread.

The loss of moisture content was not significantly correlated to storage period. Swelling power determinations correlated most closely to organoleptic evaluation of bread freshness ($r = 0{\cdot}916$). Since swelling power determination is a simple and rapid test, it may be recommended as a useful measurement of staling and shelf life of Egyptian-type bread. Maleki & Seibel (1972) established a correlation coefficient of 0·88 between organoleptic and penetrometer values for measuring staling rate by compressibility in American-type raised bread. However, this type of crumb compressibility measurement is not applicable to the almost crumb-free Egyptian type breads.

REFERENCES

American Association of Cereal Chemists (1958). *Approved Method of the AACC.* Method 85.5b. AACC, St Paul, MN.

American Association of Cereal Chemists (1976). *Approved Method of the AACC.* Method 44-15A. AACC, St Paul, MN.

Atia, A. A. (1986). Physical and chemical studies on the staling of some Egyptian bread. PhD Thesis, Food Science Department, Faculty of Agriculture, Cairo University.

Bic, C. & Geddes, W. F. (1949). Evaluation of methods for measurement of changes which occur during staling. *Cereal Chem.*, **26**, 440.

Bradley, W. B. & Thomson, J. B. (1950). The effect of crust changes in crumbliness and compressibility of bread crumb during staling. *Cereal Chem.*, **27**, 331.

D'Appolonia, B. L. & Morad, M. M. (1981). Bread staling. *Cereal Chem.*, **58**, 186.

Dragsdorf, R. D. & Varriano-Marston, E. (1980). Bread staling: X-ray diffraction studies on bread supplemented with α-amylase from different sources. *Cereal Chem.*, **57**, 310.

Fahmy, A. H. & Mansour, S. M. (1982). Studies on staling of bread. I. Amylolytic digestion of staled Balady bread. Paper presented at First Egyptian Conference on Bread Reearch, Ministry of Agriculture, Field Crops Research Institute, Giza, Egypt, 9–11 Nov.

Faridi, H. A. & Rubenthaler, G. L. (1984). Effect of baking time and temperature on bread quality, starch gelatinization and staling of Egyptian Balady bread. *Cereal Chem.*, **61**, 151.

Larmond, E. (1970). *Methods for Sensory Evaluation of Foods*. Publication No. 1284, Department of Agriculture, Ottawa, Canada.

Leach, H. W. (1963). Determination of intrinsic viscosity of starch *Cereal Chem.*, **40**, 593.

Maleki, M. & Seibel, W. (1972). Uber das Altbackenwerden von Brot. I. Beziehungen zwischen Sensorik, Penetrometer und panimeter bein Messen des Altbackenwerdens von Weizenbrot. Getreide Mehl Brot., **26**, 58.

Morad, M. M. & D'Appolonia, B. L. (1980). Effect of surfactants baking procedure on total water-solubles and soluble starch in bread crumb. *Cereal Chem.*, **57**, 141.

Pisesookbunterng, W., D'Appolonia, B. L. & Kulp, K. (1983). Bread staling studies. II. The role of refreshening. *Cereal Chem.*, **60**, 301.

Prentice, N., Cuendet, L. S. & Geddes, W. E. (1954). Studies on bread staling. V. Effect of flour fractions and various starches on the firming of bread crumb. *Cereal Chem.*, **31**, 988.

Varriano-Marston, E., Ke, V., Huang, G. & Ponte, J. (1980). Comparison of methods to determine starch gelatinization in bakery foods. *Cereal Chem.*, **57**, 242.

Waldt, L. M. & Mahoney, R. D. (1967). Antifirming of white bread by application of heat-stable bacterial alpha-amylase. *Cereal Sci. Today*, **12**, 358.

Willhoft, E. M. A. (1973). Recent developments on bread staling problem. *Bakers Digest*, **47**, 14.

Yasunaga, T., Bushuk, W. & Irvine, G. N. (1968). Gelatinization of starch during bread baking. *Cereal Chem.*, **45**, 269.

Zobel, H. F. & Senti, F. R. (1959). The bread staling problem. X-ray diffraction studies on breads containing a cross-linked starch and a heat-stable amylase. *Cereal Chem.*, **36**, 441.