Asian Journal of Chemistry Vol. 21, No. 5 (2009), 3910-3920

Effects of Wheat Flour and Baking Temperature on the Quality of Iranian Flat Bread-Part I: Physico-chemical Properties

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Information on the temperature of the environment in which the dough is produced as well as the temperature of oven are very important at different stages of preparing dough and baking bread. Three wheat cultivars and three baking temperatures (232, 249 and 260 °C) were used for baking samples of dough in an electric oven. Initially, physico-chemical characteristics of Iranian flat bread made of three wheat cultivars is investigated. Thickness of dough after secondary proof, increase in bread volume, decrease in dough weight during baking and the duration of baking time were measured. Statistical analysis revealed that the effect of wheat cultivar on bread volume, decrease in dough weight during baking and baking time were statistically significant at the 1 % level. Maximum increase in bread volume dedicated to Chamran cultivar as 806.7 mL at 260 °C. Minimum decrease in dough weight was 15.26 g, related to Chamran cultivar at 260 °C, while the maximum was 38.93 g, in Pishtaz cultivar at the same temperature. Minimum and maximum baking times were 10 and 17 min, related to Chamran and Marvdasht cultivars at 260 and 232 °C, respectively.

Key Words: Flat bread, Dough, Physico-chemical, Wheat flour, Baking.

INTRODUCTION

Wheat has a prominent position among all cereal grains in the world and as the most important cereal grain in Iran. While it is the cheapest and most stable source of proteins and calories in most of the Middle East countries. Its average consumption can supply up to 30 and 49 % of human energy and protein requirements, respectively[1]. Baking is crucial in determining the quality of bread. During baking process of dough undergoes a series of physical, chemical and biochemical changes in dough, as well as changes in colour[2]. During baking, different ingredients such as oxidizing agents, salts, *etc.* are added to improve bread quality. The action of ingredients during baking can be controlled if the chemical and physical changes during the baking process are well understood[3]. The changes of dough during baking are classified as physical and chemical changes. The film formation, the expansion of gases within gluten net, the reduction of solubility of gases and the evaporation of

alcohol and other liquids such as water are the examples of the physical changes. The chemical changes include the intensification of the yeast activity, the synthesis of the carbon dioxide, the gelatinization of starch, the coagulation of gluten, the caramelized of starch and other sugar and the browning reaction of the bread. After the entrance of dough to the oven, initially the biological reactions are intensified due to the soaring of the temperature. These changes occur at different temperatures and largely affect the physical characteristics of the final product[4]. In all thermo-production processes including bread baking, thermo-physical properties are important factors in the control of the quality. Information on the temperature of the environment in which the dough is produced as well as the temperature of oven is very important at different stages of preparing dough and baking bread. To study these effects on the physical characteristics of the bread, their characteristics have to be examined.

A limited number of researches have been done on flat bread throughout the world. Qarooni[5] reported the flour quality requirements for different flat breads such as baladi, chapatti, barbari, tanoor, sangak and arabic bread. Flat breads such as Lavash, Taftoon, Baribari and Sangak are generally produced from high-extraction wheat flours, that is, those containing substantial amounts of bran and germ[6]. High-extraction wheat flours are less stable than white flours. Prolonged storage of high-extraction flours often leads to the development of rancidity. Rancidity includes adverse quality factors arising directly or indirectly from reactions with endogenous lipids, producing a reduction in baking quality of the flour, undesirable tastes and odors and/or unacceptable functional properties. Among bread types, they have a better chance of incorporation of high levels of dietary fiber without causing a drastic deterioration in quality[7]. Among the different Iranian flat breads, Lavash is the most consumed and has the highest losses (39.1 %) followed by Baribari (13.8 %) and Sangak (10.7 %) during baking, handling, distribution and consumption processes[4-6]. Akram *et al.*[8] studied the trend of the temperature and humidity variations during the qualitative baking of Baribari in an electric oven. In bread baking practice, material properties which changes with temperature and moisture content are not readily available. Zanoni and Petronio[9] explored the effects of temperature and relative humidity on the specific heat of the bread. Coskuner and Karababa[10] studied the effect of different levels of triticale flour on the rheological and sensory characteristics of a range of Turkish flat breads made with blends of triticale with two bread wheat cultivars.

The objective of this work was to examine the effects of wheat flour cultivars (Pishtaz, Marvdasht and Chamran), different baking temperatures and their interactions on physiochemical properties of Iranian flat bread. The prepared samples of dough were baked in an electric oven maintained at temperatures of 232, 249 and 260 °C. In Part II, the design of a pilot-scale set-up for automating the measurments as well as the trends of temperature variations at the top, middle and bottom of flat bread made of these cultivars will be presented and discussed[11].

EXPERIMENTAL

Study of determinative traits of wheat, flour and dough quality: In this study, the various wheat flours including Pishtaz, Marvdasht and Chamran (three native Persian varieties) and different baking temperatures as two factors affecting different characteristics of bread were examined. Considering the effects of physical and chemical properties of different wheat cultivars and the properties of resulting flour and dough on physical characteristics of bread, initially they were studied. Then, the prepared samples of dough were baked in an electric oven maintained at temperatures of 232, 249 and 260 °C. Physical characteristics of different wheat cultivars including 1000 seed weight, injure bug, efficient loss, inefficient loss and grain colour were evaluated. Some physical characteristics such as moisture content percentage, bread volume and grain hardness were determined by Inframatic 8100. According to the relevant diagrams, the amount of water, required time for soaking and secondary moisture content percentage of each cultivar was determined. All cultivars were soaked in a calculated amount of water for 24 h and then milled by Brabender Type 279002. 100 g of each cultivar was sampled and milled by Laboratory Mill 3100. Chemical characteristics of various cultivars such as protein content percentage and Zeleny number were determined by Inframatic 8100. The flour gluten content was determined through both wet and dry method[12]. In wet method, samples were rinsed with tampon solution by Glutamatic-2100. Rinsing process was carried out in two stages by two filters with different mesh number. In the second method, wet gluten samples were dried by Glutork 2020 and weighed by Precisa 1600C with the accuracy of ± 0.01. Centrifuge 2015 was used for determining the gluten quality. To find the elasticity of gluten, samples tension, dryness and softness were evaluated. The activity of alpha-amylases of sample was determined by Falling Number. The Falling Number was determined using the AACC protocol (AACC method 56-81b[12]). Mechanical characteristics of flour and dough including resistance, expansion time, durability and sagging degree of dough in terms of Farino were determined according to ICC Standard-115[13] by Bra Bender Farinograph Type 820600. Valorimetric value was used for verifying the strength and weakness of dough.

Baking: Three different doughs were made using three commercial wheat flours (Pishtaz, Marvdasht and Chamran) following the recipe listed in Table-1. The basic properties of the flours are summerized in Table-2. Dough was combined of flour, sodium chloride, dry yeast, sugar and water. To obtain better results, firstly dry components were mixed and then water was added. The breads were baked using the parameters listed in Table-1. To provide the yeast solution, 2.5 g of leaven, 1.5 g of salt and 1 g of sugar per 100 g of flour of each cultivar were mixed and then calculated amount of water by farinograph was added. Resulting solution was added to flour and according to RMT method in laboratory temperature (26-27 °C) was mixed by a mixer with the circular speed of 1400 rpm for 1 min. Thereafter dough was put in a steel container and was maintained in incubator (Cenco Model No.

TABLE-1
BREAD FORMULATION FOR EACH BATCH OF DOUGH

Ingredient	Amount
Flour (g)	400
Water (mL)	*
Sugar (g)	4
Active dry Yeast (g)	4
NaCl (g)	10
Salt (g)	6
Leaven (g)	10

*For each cultivar the amount of water required was calculated by farinograph.

TABLE-2
PHYSICAL AND CHEMICAL CHARACTERISTICS OF DIFFERENT WHEAT CULTIVARS

Property	Wheat cultivar		
	Pishtaz	Chamran	Marvdasht
Bread volume (cc)	420.34 ± 0.57	513.12 ± 0.23	293.67 ± 0.28
Moisture (%)	11.47 ± 0.05	12.30 ± 0.01	11.30 ± 0.10
Water absorption (%)	65.87 ± 0.06	63.17 ± 0.06	57.50 ± 0.40
Protein content (%)	11.47 ± 0.06	10.90 ± 0.10	9.13 ± 0.06
Zeleny Number	31.67 ± 0.28	23.00 ± 0.10	14.33 ± 0.05
1000-seed weight (g)	38.00 ± 1.00	38.00 ± 1.00	34.00 ± 1.00
Injured bug (%)	0.30 ± 0.10	0.00 ± 0.00	0.50 ± 0.10
Efficient loss (%)	1.00 ± 0.00	0.00 ± 0.00	2.00 ± 1.00
Grain colour	Red	Yellow	Yellow

95086) in temperature of 30-32 °C and relative humidity of 80 % for 0.5 h. The second stage of preparing dough was its proving. To provide the suitable condition for reactivation of yeast, dough was kneaded for 1 min in order to exit the produced gases in initial fermentation process. Dough was flattened on a 40 × 20 cm^2 aluminum tray with the thickness of 10 mm and was put in incubator for 45 min in order to secondary proof. Then the thickness of dough was measured in three points by using a ± 0.1 mm accuracy calliper and its average amount was considered as the thickness of dough.

The prepared samples of dough were baked in an electrical oven with the dimensions of 875 mm × 865 mm × 680 mm. To measure and control temperature variations at top, middle and bottom of bread during backing, an automatic computer-based monitoring system was developed. Details of this pilot-scale set-up is given in Part II[11]. The bread was baked with emergency no-time method. Duration of baking was recorded by chronometer. To determine the decrease in bread weight during baking, four samples with same weight were selected and baked in different temperatures studied. The weight of all bread loaves after being in electrical oven for 8, 10, 12 and 14 min and their moisture content and weight loss were carefully measured.

The volume of loaves was measured by National Loaf Volumemeter (suitable for volumes less than 1000 mL) according to the method of substitution of rape seed. To determine voluminous density of loaves, bread weight was calculated 0.5 h after baking and divided by its volume.

Statistical analysis: In this study, the various cultivars of wheat (Pishtaz, Marvdasht and Chamran) and baking temperatures in three levels (232, 249 and 260 °C) as two factors affecting different characteristics of bread were examined based on a factorial statistical design. Nine treatments in the form of completely randomized fundamental design with three replications and in total, 27 samples were baked. Once the variance analysis of the resulting data based on factorial design model between different levels of two main factors and interaction between them showed a significant difference, mean major effects of factors on observed characteristics as well as their interaction were classified through Duncan's multiple ranges test method ($p < 0.05$). The MINITAB version 14.1 software was used for statistical analysis (www.minitab.com).

RESULTS AND DISCUSSION

Physical and chemical properties: The results of the measurement of physical and chemical properties of all three wheat cultivars are summarized in Table-2. According to the results, Pishtaz cultivar has more protein percentage, Zeleny number, water absorption percentage and grain hardness than Chamran and Marvdasht cultivars. There is a correlation between farinograph properties (water absorption and dough stability) and bread volume[13]. High protein content in Pishtaz can be attributed to higher grain hardness. This suggests that Pishtaz wheat is stronger than the two other wheat cultivars and thus has a better quality for bread making. Nevertheless, all three cultivars are classified as poor wheat from the point view of protein percentage. Zenely number for Pishtaz, Chamran and Marvdasht cultivars are in the range of rich, moderate and poor wheat, respectively. Pishtaz cultivar may have more yield than that of other cultivars due to higher level of water absorption. Considering thousand-seed weight, Pishtaz and Chamran cultivars are moderate and Marvdasht cultivar is small-grain.

Qualitative and quantitative characteristics of gluten: The results of measurement of qualitative and quantitative characteristics of gluten for all three cultivars are shown in Table-3. According to the results, from the point view of gluten amount, Pishtaz and Chamran cultivars are moderate cultivars and Marvdasht is a poor one. Nonetheless, quality index and gluten content percentage of Chamran cultivar are greater than that of Pishtaz and Marvdasht cultivars. The results of elasticity test of dough showed that Chamran cultivar has more elasticity than that of other cultivars in spite of higher protein content of Pishtaz cultivar. Higher elasticity is due to higher quality of gluten in cultivar Chamran. Therefore it maintains a higher level of gas during baking which in turn, leads to an increase in bread volume, cavities and its porosity. The study of qualitative characteristics of the bread considered

TABLE-3
QUALITATIVE AND QUANTITATIVE CHARACTERISTICS OF GLUTEN FOR ALL THREE CULTIVARS

Gluten characteristic	Wheat cultivar		
	Pishtaz	Chamran	Marvdasht
Under-screen gluten	0.55 ± 0.05	0.60 ± 0.10	1.27 ± 0.06
On-screen gluten	2.30 ± 0.10	2.40 ± 0.10	1.67 ± 0.11
Total gluten (%)	2.85 ± 0.15	3.03 ± 0.10	2.94 ± 0.06
Gluten quality index	80.50 ± 0.50	81.07 ± 0.50	56.67 ± 1.52
Dry gluten (%)	11.50 ± 0.50	10.92 ± 0.20	10.01 ± 0.20
Gluten elasticity	Tough	Normal	Slack

confirms this finding. The results of α-amylase activity measurement showed that falling numbers of cultivars of Chamran, Marvdasht and Pishtaz are 232-250, less than 200 and more than 500, respectively. So in this respect, Chamran cultivar is better than other cultivars, too.

Farinograph test: It has been frequently documented by many researches that a dramatic change of physical and chemical property of dough takes place during baking. Such changes recorded using farinnograph are shown in Table-4. Softening index after 10 and 20 min indicates that Marvdasht cultivar declies more rapid than Pishtaz cultivar. Hence, the period of dough puffing is shorter in this cultivar. The required time to reach the peak of farinograph diagram in Chamran, Pishtaz and Marvdasht cultivars were 3.5, 1.8 and 1.5 min, respectively which shows the higher quality of gluten in Chamran. Boggini *et al.*[14] suggested that Durum wheat cultivars with strong gluten properties would be suitable for bread making and that protein content and gluten in subunit composition are the key factors in determining the bread making properties of Durum wheat. Considering the latter fact, Chamran cultivar should be most approprite for bread making. This findings is in agreement with that of Toufeili *et al.*[15] in which pointed out the bread making performance of wheat flour is governed by the quantity and quality of its proteins and flours of high protein content often yield bread with good quality. However, flours with the same protein content do not necessarily produce breads of similar quality. Also, the time of kneading and durability of dough in Chamran cultivar are greater than Pishtaz and Marvdasht cultivars. Consequently, the resistance of the dough of this cultivar against mechanical mixer and its durability will be greater than others. The valorimetric values (BU) of the flours of Chamran, Pishtaz and Marvdasht were 56, 47 and 42 %, respectively which shows that they can be classified as good, medium and poor flours, respectively. The valorimetric values, which represent the physico-mechanical properties of the dough, were all higher than the minimum acceptable 40 BU[16]. In general, medium strength doughs are preferred for flat bread-making, beacause if the dough is too strong it will not react properly during the sheeting or flattening processes involved during the baking. This is in contrast to the western-style raised breads[10].

TABLE-4
SOME RESULTS OF FARINOGRAPH TEST OF WHEAT CULTIVARS PISHTAZ, CHAMRAN AND MARVDASHT

Classification	Wheat cultivar		
	Pishtaz	Chamran	Marvdasht
Softening degree after 10 min (farino)	65.0 ± 1.0	65.00 ± 1.00	135.00 ± 1.00
Softening degree after 20 min (farino)	100.0 ± 1.0	130.00 ± 2.00	220.00 ± 3.00
Development Time (min)	1.8 ± 0.1	3.51 ± 0.08	1.52 ± 0.08
Dough Resistance (min)	5.0 ± 0.5	6.10 ± 0.50	3.30 ± 0.20
Valorimetric value (%)	47.0 ± 1.0	56.00 ± 1.00	42.00 ± 1.00

Dough characteristics: The measurements of characteristics including bread volume, the decrease in dough weight during baking, dough thickness after secondary proof and the baking time of bread are shown in Table-5. Considering the results of variance analysis of the effects of cultivar on bread volume increase, the decrease in bread weight during baking and baking time were significant at the 1 % level of significance and dough thickness after secondary proof did not exhibit a significant difference. The increase in the bread volume was in the range of 537-752 cm^3. Mean comprison through Duncan's multiple ranges test showed that Marvdasht cultivar significantly had lower bread volume. But the difference of bread volume between Pishtaz and Chamran cultivars was non significant. Difference among the bread volume values can be associated with the variation in the potential for gas retention among wheat flour doughs that this phenomenon is largley due to variation in bulk rheological properties[17]. Previous research has indicated a correlation between farinograph properties (water absorption and dough stability) and bread volume[13]. The behaviour of wheat flour dough is also related to gluten strength and content. According to Payan[4], the amount and quality of dough gluten are the main factors affecting bread volume increase and its porosity. Thus the lower bread volume resulted from Marvdasht cultivar may be due to the lower amount and quality of its gluten. This result is in close agreement with Boggini *et al.*[14] who reported that Durum wheat cultivars with strong gluten properties would be suitable for bread making. In the study conducted by Roels *et al.*[18] no relationship was found between protein quality and loaf volume when dough mixing was optimized. This is in contrary with what is found in the present work. The authors concluded that breads formulated with lower gluten flour had higher quality and volumes. The variation in the range of bread volume decrease is 17.5-29.8 g per 100 g of dry flour. Marvdasht and Chamran cultivars had the highest and the lowest decrease in bread weight, respectively whereas the difference between bread weight decrease in Pishtaz and Chamran cultivars was not significant. Considering inverse relationship between dough yield and bread weight decrease, Chamran had higher yield than other cultivars. The range of bread baking time of Marvdasht and Chamran cultivars was significant whereas there was not a significant difference between Pishtaz and Chamran cultivars in this sense. Chamran had the shortest baking time (11.2 min).

TABLE-5
EFFECT OF CULTIVAR ON CHARACTERISTICS INCLUDING VOLUME, WEIGHT DECREASE, BAKING TIME OF BREAD AND DOUGH THICKNESS AFTER SECONDARY PROOF

Characteristics	Wheat cultivar*		
	Pishtaz	Chamran	Marvdasht
Bread volume[a] (mL)	683.89 a	752.22 a	537.56 b
Weight decrease[a] (g)	30.52 b	17.52 a	29.85 b
Dough thickness[ns] (mm)	19.88	20.64	20.22
Baking time[a] (min)	12.89 b	11.22 a	14.00 b

[a]Corresponding to confidence level of 99 %; [ns]Corresponding to no significant difference;
*The means with minimum common letter are not significantly different ($p < 0.05$) according to Duncan's multiple ranges test.

Effect of baking temperature: The result of examining the effect of baking temperature on measured characterisitcs is shown in Table-6. The baking temperature has significantly affected baking time, bread weight decreased during baking at the 1 % probability level and bread volume increased at the 5 % probability level. The variation of bread volume was in the range of 617-703 mL and the highest bread volume was gained in the temperature of 249 °C. The variations in bread volume as affected by baking temprature can be attributed to the amount of gluten of each wheat cultivar. The variation of baking time was 11-15.2 min for all baking temperatures and the lowest time was obtained at the temperature of 260 °C. Mean comprisons *via* Duncan's multiple ranges test showed a significant difference among 232 °C with others (249, 260 °C), whereas the duration of baking time did not changed significantly from 249 to 260 °C. Therefore, it is recommended to use baking temperature of 249 °C in order to save energy and time. This optimum temperature profile will produce the lowest weight loss during baking while the crust colour and internal temperatures are maintained within an acceptable range[19]. These authors developed a quadratic model to describe the effect of baking temperature and time on the bread quality attributes including crust colours, crumb temperature and weight loss.

TABLE-6
EFFECT OF BAKING TEMPERATURE ON BREAD VOLUME, WEIGHT DECREASE AND BAKING TIME

Characteristics	Temperature (ºC)		
	232	249	260
Bread volume[b] (mL)	617.22	702.78	653.67
Weight decrease[a] (g)	24.25	23.74	29.89
Baking time[a] (min)	15.00	12.11	11.00

[a]Corresponding to confident level of 99 %; [b]Corresponding to confident level of 95 %.

The interaction effect of cultivar and different baking temperatures on measured characteristics are shown in Table-7. This interaction effect was significant on bread volume at the 5 % level as well as on weight decrease and baking time at the 1 % level. But the dough thickness values after secondary fermentation were not

TABLE- 7
INTERACTION EFFECT OF WHEAT AND BAKING TEMPERATURE ON VOLUME, WEIGHT DECREASE, BAKING TIME AND DOUGH THICKNESS

Baking temperature (ºC)	Wheat flour cultivar					
	Pishtaz			Chamran		
	232	249	260	232	249	260
Bread volume[b] (mL)	721.7abc	706.67abc	623.3cd	663.3bc	786.7ab	806.7a
Weight decrease[a] (g)	30.04e	22.58bcd	38.93e	20.25abc	17.05ab	15.26a
Dough thickness[ns] (mm)	19.33	20.67	19.67	19.5	20.77	21.67
Time[a] (min)	15.67e	12bcd	11ab	12.33bcd	11.33abc	10a
Density (g/cc)	0.422	0.440	0.498	0.465	0.396	0.389
Moisture decrease[b] (%)	8.9	6.8	11.4	6.2	5.2	4.6
Baking temperature (ºC)	Marvdasht					
	232	249	260			
Bread volume[b] (mL)	466.7e	615d	531de			
Weight decrease[a] (g)	22.246bcd	31.6e	35.48e			
Dough thickness[ns] (mm)	19.67	21	20			
Time[a] (min)	17e	13cd	12bcd			
Density (g/cc)	0.665	0.469	0.538			
Moisture decrease[b] (%)	4.1	9.8	11			

[a]Corresponding to confidence level of 99 %; [b]Corresponding to confident level of 95 %;
[ns]Corresponding to no significant difference.

statistically different. The results of measuring the volumetric density and decrease in moisture per cent indicated that Chamran cultivar at the temperature of 260 °C and Marvdasht cultivar at the temperature of 232 °C had the lowest and the highest voluminous density values, respectively. Pishtaz cultivar at the temperature of 260 °C and Marvdasht cultivar at the temperature of 232 °C had the highest and the lowest decrease in moisture per cent, respectively. The voluminous density values of the bread were in the range of 0.389-0.665 g/mL and the decrease in moisture per cent magnitudes were in the range of 4.1-11.4 % that has a negligible difference from the findings of Unklesbay and Unklesbay[20].

From the results shown in Fig. 1, Chamran cultivar at the temperature of 260 °C (and Marvdasht cultivar at 232 °C) has the biggest (and the smallest) increase in bread volume. All these cultivars reach to the highest increase in bread volume at a certain temperature, so each one has to be baked in that temperature. Based on the results shown in Fig. 2, it can be stated that Chamran and Marvdasht cultivars at the temperature of 260 °C have the lowest and the highest decrease in weight, respectively. According to this diagram, cultivars with high, moderate and poor quality had the lowest decrease in weight at the temperatures of 260, 249 and 232 °C, respectively. Chamran cultivar had the lowest decrease in weight in all three temperatures. From Fig. 3, it is evident that Chamran and Marvdasht cultivars had the shortest and the longest baking time at all three temperatures, respectively. However, among the three cultivars, the shortest baking time was gained at the temperature of 260 °C.

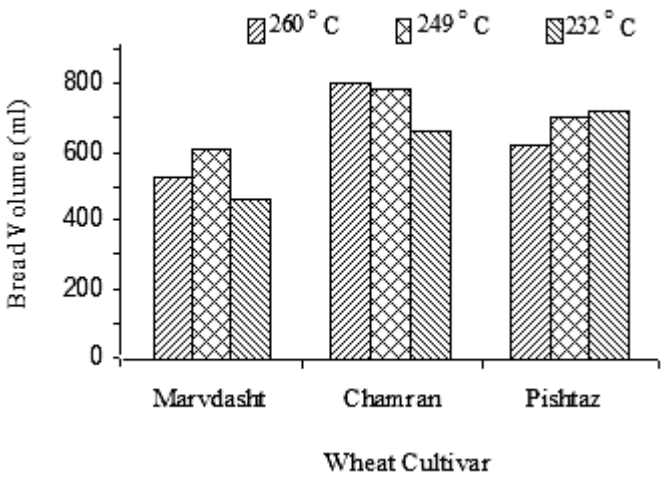

Fig. 1. Effect of wheat cultivar at different baking temperatures on bread volume

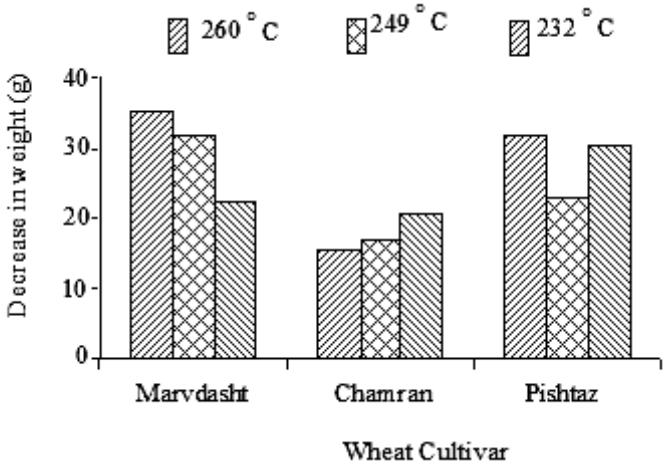

Fig. 2. Decrease in bread weight during baking at different temperatures

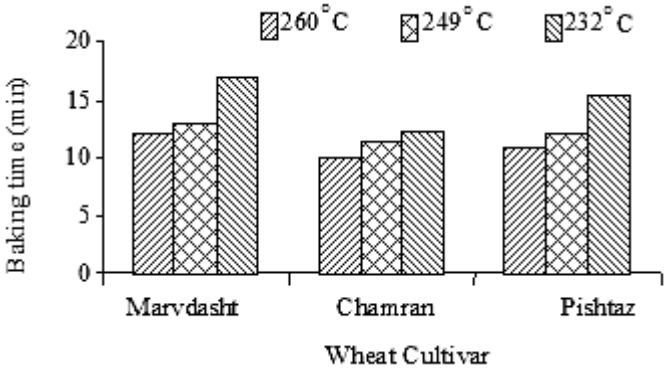

Fig. 3. Comparison of bread baking time for cultivars at different temperatures

ACKNOWLEDGEMENT

The financial support provided by the Research Department of University of Tehran is gratefully acknowledged.

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(*Received*: 22 August 2008; *Accepted*: 23 February 2009) AJC-7267