Dough performance, quality and shelf life of flat bread supplemented with fractions of germinated date seed

Sudiyeh Hejri-Zarifi · Zahra Ahmadian-Kouchaksaraei ·
Amir Pourfarzad · Mohammad Hossein Haddad Khodaparast

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Abstract Germinated palm date seeds were milled into two fractions: germ and residue. Dough rheological characteristics, baking (specific volume and sensory evaluation), and textural properties (at first day and during storage for 5 days) were determined in Barbari flat bread. Germ and residue fractions were incorporated at various levels ranged in 0.5–3 g/100 g of wheat flour. Water absorption, arrival time and gelatination temperature were decreased by germ fraction but accompanied by an increasing effect on the mixing tolerance index and degree of softening in most levels. Although improvement in dough stability was monitored but specific volume of bread was not affected by both fractions. Texture analysis of bread samples during 5 days of storage indicated that both fractions of germinated date seeds were able to diminish bread staling. Avrami non-linear regression equation was chosen as useful mathematical model to properly study bread hardening kinetics. In addition, principal component analysis (PCA) allowed discriminating among dough and bread specialties. Partial least squares regression (PLSR) models were applied to determine the relationships between sensory and instrumental data.

Keywords Barbari bread · Dough · Staling · Sensory properties · Multivariate analysis

S. Hejri-Zarifi (✉)
Department of Food Science, Sabzevar Branch,
Islamic Azad University, Sabzevar, Iran
e-mail: sudiyeh81@yahoo.com

Z. Ahmadian-Kouchaksaraei · M. H. H. Khodaparast
Department of Food Science and Technology,
Ferdowsi University of Mashhad, Mashhad, Iran

A. Pourfarzad
Department of Food Science and Technology,
Malayer University, Malayer, Iran

Introduction

Dates of date palm tree (*Phoenix dactylifera* L.) are popular among the population of the Middle Eastern countries. The fruit is composed of a fleshy pericarp and seed which constitutes between 10 % and 15 % of date fruit weight (Hussein et al. 1998). The date seeds considered a by-product of many date processing plants producing pitted dates, date syrup and date confectionery. At present, seeds are used mainly for animal feeds in the cattle, sheep, camel and poultry industries. With world production of dates reaching 7.7 million tonnes in 2010, from this approximately 963 thousand tonnes of date seeds are produced (FAO 2012). Thus, the utilization of such by-product is very important for date cultivation and increasing of the income of this sector.

Chemical composition of date seeds showed high amounts of carbohydrates (75–80 %), fat (10–12 %) and proteins (5–6 %) (Besbes et al. 2004a). This by-product of date-processing industries could be regarded as an excellent source of food ingredients with interesting technological functionality that could also be used in food as an important source of dietary fiber (Besbes et al. 2004b; Bouaziz et al. 2008).

For centuries, seeds have been germinated for food or feed uses. For many seeds, appropriate germination conditions can increase several vitamins (Kim et al. 2012), increase relative nutritive value and protein efficiency ratio (Martínez-Villaluenga et al. 2008) and reduce some seed antinutritional factors (El-Adawy 2002). Also, germination sometimes increases phytase activity, reduces phytate content and thereby probably increases mineral availability (Ou et al. 2011; Azeke et al. 2011).

Flat breads are the main dietary staple in many Middle Eastern and North African countries. In today's demanding world, the use of natural bread improvers has become an indispensable part of enhancing the quality of bakery products.

Few works are interested to study the supplementation of bread with a palm date seed powdered. Bouaziz et al. (2010) investigated the effect of defatted date seeds on wheat dough performance and bread quality. Heated defatted Agwa and Aprimi seeds, added at levels of 1 and 3 %, enhanced bread quality and shelf life (Wasif 1996). Almana and Mahmoud (1994) showed that the coarse fraction of date seed affected the mixing characteristics and extensography parameters in a relatively similar manner to wheat bran, but the fine fraction behaved in a different manner, they caused deterioration in bread color, flavor, odor, chewing, uniformity and overall acceptability.

Thus, the present study was designed: (a) to examine the effects of germ and residue of date seed on dough rheology, quality, shelf life and sensory aspects of flat bread; (b) to obtain the relationship between dough and bread parameters by using multivariate mathematical-statistical methods such as partial least squares regression analysis (PLSR) and principal components analyses (PCA).

Materials and methods

Materials

Commercial *Triticum aestivum* wheat flour (locally named Setareh) was procured from the AceeArd Co., Khorasan, Iran. Dried active yeast was obtained from Fariman Co., Khorasan, Iran. Date fruit (*Phoenix dactylifera* (L.), var Kabkab) was obtained from Fars area in Iran.

Methods

Chemical and physical analysis of flour and date pits

Moisture (44–16 A), protein (46–13), ash (08–07), fat (30–10), wet gluten (38–11), falling number (56–81) and crude fiber (32–10.01) were determined according to standard AACC methods (2000). Carbohydrate content was estimated by difference of all compounds from 100.

Preparation of date germ and residue

An important commercial variety of date fruits, namely Kabkab (*Phoenix dactylifera* (L.), var Kabkab), used in this study were collected in the Fars area in Iran. The seeds were removed from the fruits, soaked in water and washed to free them from any adhering date flesh. Date seeds were treated under thermal shock conditions (1 h at 38 °C) to stimulation and accelerate of germination. Then, they were placed on vertical moist filter paper in a closed container and allowed to stand in a constant temperature room at 30 °C for 2 weeks. 2–3 cm germs were removed from the seeds, air-dried for 1 h at 50 °C and milled to powdered date germs

(100 mesh). Also, date seed residues were air-dried for 1 h at 70 °C and then ground to 100 mesh. Both powders of germs and seed residues were packed in polyethylene bags and preserved at room temperature before using. The levels of germ were varied into 4 levels: 0, 0.5, 1 and 1.5 g/100 g based on wheat flour. Amounts of residue were added into 4 levels: 0, 1, 2 and 3 g/100 g of wheat flour. The results of our pre-test indicated that these ranges yield have the proper functional properties of dough and bread.

Rheological properties of dough

The effect of germ and residue of date seed on dough rheology during mixing was examined with the Farinograph (Brabender, Duisburg, Germany) following official standard method 54–21.01 (AACC 2000). The determined parameters were:

Water absorption (WA) was defined as the amount of water required to centre the highest part of the mixing curve on the arbitrary 500 BU (Brabender units) line. Arrival time (AT) was the time required for the curve to reach the 500 BU line. Dough development time (DDT) was the time interval (in min) from the first addition of water until the curve reaches its maximum height. Stability was the time in minutes for which the top of the curve remains over 500 line. Mixing tolerance index (MTI) was the difference in BU from the top of the curve at peak time to the top of the curve 5 min after the peak is reached. Degree of softening (DOS) was the distance between the centre of the mixing curve and the 500 line after 20 min mixing.

The gelatination temperature (GT) was defined as temperature at maximum consistency and determined with the Amylograph (Brabender, Duisburg, Germany) according to standard manner 22–10.01 (AACC 2000).

Bread making and evaluation

The bread investigated in this study was “Barbari”, which is one of the most consumed flat breads in Iran. This bread was produced using a standard method described by Pourfarzad et al. (2011). After cooling, bread samples were packed in polyethylene bags, stored at room temperature and evaluated. Quality analysis of fresh bread samples was carried out by measuring specific volume of the central slice (rapeseed displacement). To determine specific volume, slices of 10 × 10 mm were cut from the center of the bread samples using a metal template (Pourfarzad et al. 2011).

Sensory evaluation

Sensory analysis was carried out using a 5-point ranking scale with scores ranging from 1 (least pleasure) to 5 (best pleasure). Sensory evaluation was performed by 10 trained panelists. Attributes of bread were selected according to the

Iranian flat bread evaluation method, including bread form and shape; upper and bottom surface properties (all undesirable bread features which has been created due to temperature changes in oven i.e., wrinkles and dark brown color of bread surface); cavity and porosity (unusual pores and aggregation in cross-section of bread crumb); firmness and softness of texture (being pasty and have unusual softness); chewing ability; odor, flavor and taste and overall quality score (total acceptance) (Rajabzadeh 1991). For each of the attributes, the average of the panelist scores was calculated.

Texture analysis

Staling phenomenon and its changes were evaluated by penetration test. A texture analyzer (model QTS 25 kg, CNS Farnell, Hertfordshire, UK) was used to measure the force required for penetration of a round-bottom (2.5 cm diameter $\times$ 1.8 cm height) probe at a velocity of 30 mm/min into the bread samples. The probe descended 30 mm (a sufficient distance to pass through the slice of 10 $\times$ 10 cm of bread) and the trigger force was set at 0.05 N (Pourfarzad et al. 2011). The bread samples were evaluated 2, 24, 48 h and 5 day after baking for shelf life by monitoring the bread hardness.

Values for the Avrami model factors were estimated by fitting experimental points into the non-linear regression equation:

$$\theta = \frac{T_{\infty} - T_t}{T_{\infty} - T_0} = e^{-kt^n} \quad (1)$$

where θ is the fraction of the recrystallization still to occur, T_0 is the bread hardness at zero time, T_{∞} is the bread hardness at ∞ time, T_t is the bread hardness at t time, k is a rate constant (usually used as constant time to compare bread hardening rate) that represents the parameters characterizing the crystallization process, and n is the Avrami exponent that related to the crystal shape, way of crystallites nucleation, their subsequent growth and the time dependence of the nucleation process (Avrami 1941; Armero and Collar 1998; Zhou et al. 2008)

Regression was done by using the CurveExpert 1.3 software (Starkville, MS, USA).

Statistical analyses

In order to assess significant differences among samples, a completely randomized design was performed. Duncan's new multiple range test was used to describe means with 95 % confidence. PCA and PLSR were performed on mean dough, baking and sensory data sets. All statistical analyses were carried out using Minitab 16 software (Minitab Inc., State College, PA, USA). Results were reported as the average of three replications (all treatments were evaluated in three batches).

Results and discussion

Physicochemical characteristics of wheat flour and fractions of germinated date seed

The Physicochemical compositions of wheat flour and fractions of germinated date seed (germ and residue) are presented in Table 1. The characteristics of the flour are in the range of typical values of medium strong flour, suitable for Iranian Barbari flat bread. Date germ has a noticeable amount of protein and fat. The fiber value of both fractions of date seed (germ and residue) is high, suggesting an important source of dietary fiber for enrichment of flat breads.

Dough properties

The addition of germ and residue of germinated date seed could promote differences on the dough mixing behavior measured by the farinograph and amylograph. Table 2 shows the main parameters registered in the farinogram and amylogram. Significant variations were observed between control and dough enriched by date seed fractions ($P \leq 0.05$). Although the WA was not affected by residue, but addition of germ decreased it. The decrease of WA may be due to action of active enzymes of germ on the starch molecules hydrolyzing them to dextrins which have low water binding capacity (Stauffer 1990; Gernah et al. 2011). Similar results were observed in high protein, high fiber and low carbohydrate bread (Dhinda et al. 2012) and whole wheat bread (Shah et al. 2006). The use of germ decreased significantly ($P \leq 0.05$) the AT compared to the control but residue addition didn't any affect on this parameter. This result was similar to that reported previously (Maeda et al. 2003). This tendency could be attributed to weakening of mixed doughs caused by the

Table 1 Quality characteristics of wheat flour and fractions of germinated date seed

Attribute	Wheat flour	Fractions of germinated date seed	
		germ	residue
Moisture (%)	10.5 $\pm$ 0.36	6.9 $\pm$ 0.21	6.5 $\pm$ 0.25
Protein (%)	10.8 $\pm$ 0.24	16.6 $\pm$ 0.25	5.5 $\pm$ 0.31
Fat (%)	1.8 $\pm$ 0.51	20.2 $\pm$ 0.54	9.6 $\pm$ 0.17
Ash (%)	0.79 $\pm$ 0.01	2.1 $\pm$ 0.16	1.1 $\pm$ 0.09
Crude fiber (%)	2.5 $\pm$ 0.16	12.6 $\pm$ 0.51	22.1 $\pm$ 1.21
Carbohydrates (%)	73.6 $\pm$ 1.12	41.7 $\pm$ 1.16	55.3 $\pm$ 1.03
Wet gluten (%)	26.7 $\pm$ 0.55	—	—
Extraction rate (%)	82.1 $\pm$ 1.51	—	—
Falling number (second)	407.1 $\pm$ 3.01	—	—

Each observation is a mean $\pm$ SD of three replicate experiments ($n=3$) on wet weight basis

presence of a low molecular weight dextrin, which was produced from damaged starches by enzyme activity of germ (Kim et al. 2006). As it can be seen in Table 2, the DDT was not affected by fractions of germinated date seed. The use of both fractions of germinated date seed increased significantly the dough stability compared to the control ($P \leq 0.05$). The increase of stability may be due to the stabilizing action of components of both fractions such as protein. These results were in agreement with those found by Rosales-Juárez et al. (2008) which supplemented the bread wheat flour by the germinated and non-germinated soybean flour. Also, the addition of defatted palm date seeds in dough increased stability. On the other hand, the MTI of dough samples increased with addition of date seed germ. With the exception of residue at the lowest concentration (1 g/100 g), no differences were observed in MTI of dough. Similar behavior was observed for DOS. The addition of 0.5 and 1 g/100 g germ and 1 g/100 g residue fraction enhanced the DOS of dough. But, no statistical difference was observed between control and dough supplemented with other levels of treatments concerning DOS. These results could be explained by enzyme activity of fractions and subsequently weakening of mixed doughs (Kim et al. 2006). Moreover, the GT, commonly used to determine the cereal α -amylase activity in flour (Marnett et al. 1948) gradually decreased with the addition of the germ fraction. Results showed no significant effect of residue fraction for the GT among the samples. These results might be closely related to the increase of oligosaccharide and monosaccharide, which were synthesized by α -amylase during germination (Park and Morita 2005).

Specific volume

Volume of bread samples is a quality parameter as it indicates dough inflating ability and oven spring. As it can be seen in Table 3, specific volume of the fresh bread samples

Table 3 Specific volume of fresh Barbari bread containing fractions of germinated date seed

Treatments	Addition levels of fractions (g/100 g)	Specific volume (cm ³ /g)
Control	0	2.8 ^a
Germ	0.5	3.1 ^a
	1	3.1 ^a
	1.5	2.9 ^a
Residue	1	2.7 ^a
	2	2.9 ^a
	3	2.6 ^a
SEM ($\pm$)		(0.23)

Each observation is a mean $\pm$ SD of three replicate experiments ($n=3$)

Values in columns with different letters are significantly different ($P \leq 0.05$)

SEM standard error of the mean

was not significantly affected by all of the treatments. This result led us to the hypothesis that the dilution effect of the non-protein components in germ and residue fractions of date seed does not fully account for the depression in loaf volume. Thus, although both fractions of germinated date seed diluted gluten proteins, it does not appear to have affected the specific volume of the fresh bread. It might be due to the moderate level of protein in the treatments.

Sensory attributes

The effects of addition of date seed fractions on the sensory parameters are seen in Table 4. Results showed no significant difference for the bottom surface property, cavity and porosity among the samples. The form and shape and firmness of bread samples increased with addition of both date seed fractions in sensory analysis. The results perceived by the trained panelists showed a significant difference in chewing ability between the

Table 2 Parameters of wheat dough containing fractions of germinated date seed

Treatments	Addition levels of fractions (g/100 g)	WA (%)	AT (min)	DDT (min)	Stability (min)	MTI (BU)	DOS (BU)	GT (°C)
Control	0	64.8 ^{ab}	1.5 ^a	8.1 ^{ab}	13.1 ^c	60.1 ^c	70.1 ^c	92.1 ^a
Germ	0.5	63.4 ^d	1.1 ^b	8.1 ^{ab}	13.9 ^b	80.1 ^a	80.1 ^b	87.7 ^c
	1	63.8 ^{cd}	1.1 ^b	8.2 ^a	14.2 ^{ab}	80.1 ^a	90.7 ^a	89.1 ^{bc}
	1.5	63.6 ^d	1.1 ^b	8.1 ^{ab}	14.9 ^a	73.7 ^b	70.7 ^c	89.1 ^{bc}
Residue	1	64.6 ^{ab}	1.2 ^{ab}	7.8 ^{bc}	14.2 ^{ab}	79.3 ^a	80.1 ^b	91.3 ^{ab}
	2	64.2 ^{bc}	1.2 ^{ab}	7.9 ^{abc}	15.1 ^a	60.1 ^c	71.3 ^c	91.3 ^{ab}
	3	64.9 ^a	1.2 ^{ab}	7.7 ^{bc}	15.1 ^a	59.3 ^c	71.7 ^c	92.7 ^a
SEM ($\pm$)		(1.43)	(0.51)	(1.21)	(2.61)	(3.71)	(2.71)	(2.18)

Each observation is a mean $\pm$ SD of three replicate experiments ($n=3$)

Values in columns with different letters are significantly different ($P \leq 0.05$)

SEM standard error of the mean; WA water absorption; AT arrival time; DDT dough development time; MTI mixing time index; DOS degree of softening; BU Brabender unit; GT gelatination temperature

Table 4 Sensory characteristics of fresh Barbari bread containing fractions of germinated date seed

Treatments	Addition levels of fractions (g/100 g)	Form and shape	Upper surface property	Bottom surface property	Cavity and porosity	Firmness and softness of texture	Chewing ability	Odor, flavor and taste	Overall quality score
Control	0	3.4 ^c	4.5 ^a	3.7 ^a	3.4 ^{bc}	2.9 ^b	4.4 ^a	4.6 ^a	3.8 ^{ab}
Germ	0.5	4.6 ^a	3.9 ^{abc}	3.9 ^a	3.5 ^{bc}	4.8 ^a	3.3 ^b	3.1 ^c	3.8 ^{ab}
	1	4.6 ^a	4.5 ^a	3.5 ^a	3.1 ^c	4.8 ^a	3.4 ^b	2.9 ^c	3.8 ^{ab}
	1.5	4.1 ^{ab}	3.6 ^c	3.5 ^a	3.1 ^c	4.5 ^a	3.4 ^b	2.7 ^c	3.6 ^b
Residue	1	4.2 ^{ab}	4.1 ^{ab}	3.7 ^a	3.6 ^b	4.7 ^a	3.8 ^b	3.8 ^b	3.9 ^a
	2	4.1 ^{ab}	4.4 ^{ab}	3.7 ^a	3.4 ^{bc}	4.7 ^a	3.9 ^b	3.7 ^b	3.9 ^a
	3	4.1 ^{ab}	3.9 ^{abc}	3.8 ^a	3.5 ^{bc}	4.5 ^a	3.6 ^b	3.7 ^b	3.8 ^{ab}
SEM (±)		(0.23)	(0.16)	(0.19)	(0.26)	(0.21)	(0.24)	(0.18)	(0.17)

Each observation is a mean ± SD of three replicate experiments ($n=3$)

SEM standard error of the mean

Values in columns with different letters are significantly different ($P\leq 0.05$)

control and bread samples containing both fractions. This might be due to the crude fiber of date seed and effect of them on the mouth feel. Odor and flavor are two of the important taste characteristics in food acceptance. As it is difficult to determine a test profile by instrumental measurements, an investigation of the impact of germ and residue of germinated date seed on Barbari bread taste profile by sensory evaluation is necessary. It can be seen from Table 4 that both fractions significantly decrease the taste score and the effect of germ fraction was more than residue fraction. This might be because of the germination and subsequently special produced aroma. With the exception of germ at the highest concentration (1.5 g/100 g), no differences were observed in upper surface property and overall quality score. The high percentages of carbohydrate and protein in the germ, are the origin of high color intensity. Brown crust in bread is a result of non-enzymatic browning reaction (Maillard type) between amino acids and reducing sugars (Kent and Evers 1994). It can be concluded that germinated date seed fractions do not have any affect the sensory properties of fresh bread samples, except for germ at 1.5 g/100 g, which improves gives lower scores for overall quality score of fresh Barbari bread. Thus, it appears that both fractions may be successfully incorporated into bread without negatively impacting texture and overall acceptability, if we added the lower levels of germ. Almana and Mahmoud (1994) and Kawka et al. (1999) showed relatively similar manners about palm date seeds and barley flakes, respectively.

Texture analysis

Crumb texture is critical to consumer acceptance of baked products. The kinetic of bread hardening was modeled using the Avrami equation as reported previously for describing crystallization kinetics during storage (Comford et al. 1964;

Armero and Collar 1998). This equation has been used for explaining bread staling based on starch retrogradation, despite the contribution of the other bread components (Armero and Collar 1996). Kinetic parameters obtained from the fitted curves are shown in Table 5. The resulting adjusted models provided information on the hardness of fresh breads and on the hardening kinetics. Initial hardness (T_0) of fresh breads could be accurately estimated and varied widely from 104.38 to 202.85 g reflecting a close dependence on both the type of added fraction and the dosage supplementation. The Avrami kinetic parameters – limiting modulus (T_∞), rate constant (k), and Avrami exponent (n) – defined the shape of the firming curve along bread storage. Extreme values from the accurate

Table 5 Staling kinetic parameters during storage of breads containing fractions of germinated date seed from the adjusted mechanical characteristic hardness fitted to the Avrami equation

Treatments	Addition levels of fractions (g/100 g)	T_0 (g force)	T_∞ (g force)	n	k	R^2
Control	0	167.2 ^{ab}	361.9 ^a	0.04 ^d	1.59 ^a	0.993
Germ	0.5	104.4 ^b	252.9 ^b	0.98 ^c	0.12 ^{cd}	0.946
	1	120.6 ^b	233.6 ^{bc}	2.48 ^b	0.18 ^c	0.999
	1.5	143.5 ^{ab}	197.7 ^{bc}	3.84 ^a	0.04 ^d	0.882
Residue	1	160.6 ^{ab}	192.6 ^c	0.03 ^d	0.07 ^d	0.975
	2	152.4 ^{ab}	186.3 ^c	0.34 ^{cd}	0.07 ^d	0.935
	3	202.9 ^a	213.9 ^{bc}	0.92 ^c	0.66 ^c	0.915
SEM (±)	–	(17.28)	(21.43)	(0.258)	(0.030)	–

Each observation is a mean ± SD of three replicate experiments ($n=3$)

Values in columns with different letters are significantly different ($P\leq 0.05$)

SEM, standard error of the mean

T_0 is the bread hardness at zero time, T_∞ is the bread hardness at ∞ time, T_t is the bread hardness at t time, k is a rate constant and n is the Avrami exponent

estimation of limiting modulus were from 192.56 to 361.88 g. Bread hardening kinetics strongly depended on both k and n . High k or n values led to fast crumb firming kinetics; on the contrary, breads with low n and/or k and/or T_{∞} values were those with especially slow crumb firming kinetics. Breads containing germinated date seed fractions showed the lower constant k than the control samples, indicating slower rate for development of hardening during storage, related to the rate of crystals growing (Torre et al. 1995). Concerning the Avrami exponent n , results indicated that all levels of germ and 3 g/100 g residue increased this parameter, which has been related to the type of crystal nucleation and their growing geometry (Torre et al. 1995). It can be observed that both fractions of germinated date seed didn't give any effect on texture of fresh bread. Hardening kinetics of bread samples supplemented with both fractions was slower than kinetics of unsupplemented breads over 5 days of storage. Breads with germ fraction aged slower than samples with residue fraction along the first 24 h of storage and staled slightly faster over long-term storage up to 5 days (Fig. 1). In general, higher dosages of added germ fractions resulted in softer baked breads at 24 h of storage but it wasn't observed any difference

between different levels at other times. The hardness increase during storage has been attributed mainly to amylopectin recrystallization, although other phenomena, such as moisture diffusion between crumb and crust, and the starch–gluten interactions, has been proposed to additional players that contribute to hardness increase (Zobel and Kulp 1996). The fibrous fractions added has the ability to interact with water therefore, limiting the water available for starch gelatinization/recrystallization and likely modifying the structure of the crystals produced, as has been previously observed for some fibers (Peng et al. 2010; Collar et al. 2009). In fact, flour replacement at different levels by dietary fibers from different sources significantly modifies the qualitative and quantitative thermal profile on starch gelatinization and amylopectin retrogradation and kinetics during storage in different extend depending on the fiber source (Santos et al. 2008).

Principal Component Analysis (PCA)

Data on dough rheology, quality, shelf life and sensory aspects of flat bread were subjected to PCA (Fig. 2). The multivariate treatment of the data obtained for the bread

Fig. 1 Evolution of hardness during storage (25 °C temperature and 50 % relative humidity) of breads containing fractions of germinated date seed at different doses of addition: **a** germ fraction; **b** residue fraction; Each observation is a mean $\pm$ SD of three replicate experiments ($n=3$)

Fig. 2 Principal component analysis biplot on properties of doughs and breads containing fractions of germinated date seed; WA: water absorption; AT: arrival time; DDT: dough development time; MTI: mixing time index; DOS: degree of softening; GT: gelatination temperature; SV: specific volume; Form: form and shape; Upper: upper surface property; Bottom: bottom surface property; Cavity: cavity and porosity; Firmness: firmness and softness of texture; Chewing: chewing ability; Odor: Odor, flavor and taste; OQS: Overall quality score; H_t: bread hardness at t time

samples permitted the reduction of the variables to two principal components, which together explained 67.4 % of the total variability. The first axis accounted for 47.7 % and the second axis for 19.7 %. According to the PCA biplot, dough stability, firmness and softness of texture and cavity and porosity were positively correlated to PC2 axis whereas hardness 5 day after baking, specific volume and DDT were negatively correlated to PC2 axis. Water absorption, arrival time, Gelatination temperature, odor and chewing ability were positively correlated to PC1 axis. As clearly revealed in the PCA plot (Fig. 2) breads with selected characteristics traditionally associated with consumers' preference (sensory aspects) were those with residue fraction, which also presented the highest hardness value during 3 days after bread-making. Among dough parameters, germ containing samples were characterized by higher DDT, MTI and DOS whilst residue supplemented doughs exhibited the higher water absorption, arrival time, stability, and GT. Barbari breads containing germ fraction had relatively higher specific volume. The results depicted by PCA seemed to be in accordance with the results discussed above.

Correlation of instrumental and sensory properties of dough and bread using PLSR method

Multivariate techniques can be effectively applied to establish relationships between instrumental and sensory descriptive data. It is known that statistical methods frequently used can be either asymmetric or symmetric (Dijksterhuis 1994). The asymmetric methods (as PLSR) are especially capable of predicting one data set from the other (Martens and Martens 2001) while symmetric methods (as PCA) simply describe the relationship between data sets. PLSR was applied to investigate the relationship between instrumental X and sensory Y data. The prediction of sensory attributes by instrumental measurements is of paramount importance in food industry as it provides much information about the acceptability and quality of the final product. Moreover, the determination of quality profile of bread by instrumental measurements has the advantages of high reproducibility, convenience and directness against the assessment of sensory attributes (Sabanis et al. 2009). Thus, seven instrumental properties were used as predictors: WA, DDT, dough

Table 6 Partial least squares regression (PLSR) models for sensory features of fresh Barbari bread containing fractions of germinated date seed

Sensory attributes	Mathematical models	R ²
Form and shape	$4.633 - 0.075 \text{ WA} - 0.255 \text{ DDT} - 0.031 \text{ Stab} - 0.006 \text{ MTI} - 4.209 \times 10^{-5} \text{ H}_0 + 0.035 \text{ GT} + 1.453 \text{ SV}$	97.68
Firmness and softness of texture	$-13.893 + 0.159 \text{ WA} + 0.680 \text{ DDT} - 0.271 \text{ Stab} + 0.002 \text{ MTI} - 0.001 \text{ H}_0 + 0.112 \text{ GT} - 0.222 \text{ SV}$	57.85
Cavity and porosity	$18.587 - 0.246 \text{ WA} - 0.148 \text{ DDT} - 0.368 \text{ Stab} - 0.003 \text{ MTI} - 9.496 \times 10^{-5} \text{ H}_0 + 0.080 \text{ GT} + 0.167 \text{ SV}$	67.65
Upper surface property	$20.126 - 0.254 \text{ WA} - 0.289 \text{ DDT} + 0.175 \text{ Stab} - 0.017 \text{ MTI} + 0.0003 \text{ H}_0 + 0.018 \text{ GT} - 0.409 \text{ SV}$	70.95
Bottom surface property	$29.204 - 0.418 \text{ WA} + 0.261 \text{ DDT} + 0.233 \text{ Stab} + 0.006 \text{ MTI} + 0.0004 \text{ H}_0 - 0.049 \text{ GT} - 0.340 \text{ SV}$	52.61
Chewing ability	$-15.614 + 0.274 \text{ WA} - 0.315 \text{ DDT} - 0.136 \text{ Stab} + 0.0009 \text{ MTI} - 4.437 \times 10^{-5} \text{ H}_0 + 0.083 \text{ GT} - 0.535 \text{ SV}$	78.35
Odor, flavor and taste	$28.883 - 0.203 \text{ WA} - 0.699 \text{ DDT} + 0.351 \text{ Stab} - 0.018 \text{ MTI} + 0.0008 \text{ H}_0 - 0.109 \text{ GT} - 0.944 \text{ SV}$	76.81
Overall quality score	$8.105 - 0.071 \text{ WA} - 0.196 \text{ DDT} - 0.009 \text{ Stab} - 0.006 \text{ MTI} + 2.346 \times 10^{-5} \text{ H}_0 + 0.026 \text{ GT} + 0.007 \text{ SV}$	90.76

WA water absorption; DDT dough development time; Stab dough stability; MTI mixing tolerance index; H₀ bread hardness at 2 h after breadmaking; GT gelatination temperature; SV specific volume

stability (Stab), MTI, GT, bread hardness at 2 h after bread-making (H_0) and specific volume (SV). The predicted values for sensory attributes are calculated according to the mathematical models given in Table 6. These high coefficients are an evidence of the applicability of the regression model between the ranges of variables included.

Conclusions

This study shows how fractions (germ and residue) of germinated date seed influence the dough rheology, quality, shelf life and sensory characteristics of Barbari flat bread. Addition of germ fraction decreased water absorption, arrival time and gelatination temperature but increased stability, mixing tolerance index and degree of softening in most levels. On the other hand, Addition of residue fraction produced not much change in the farinograph and amylograph characteristics of wheat flour however, increased stability, mixing tolerance index and degree of softening in most levels. Hardening kinetics of bread samples supplemented with both fractions was slower than kinetics of unsupplemented breads over 5 days of storage. Organoleptic analysis shows that addition of germ fraction increases form and shape, firmness and softness of bread texture. Also, it was observed that addition of both fractions lead to decrease in chewing ability, odor, flavor and taste. It was proved that PCA is able to extract relevant information and offer an easy and promising approach for the interpretation of quality, shelf life, sensory and image properties of Barbari bread. Combining sensory responses and instrumental measurements by PLSR method gave valuable information in understanding and predicting the effect of different fractions of germinated date seed preparations on dough and bread quality.

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