Eur Food Res Technol (2003) 218:49–55
DOI 10.1007/s00217-003-0793-1

ORIGINAL PAPER

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Influence of durum wheat cultivar on the sensory profile and staling rate of Altamura bread

Received: 13 June 2003 / Published online: 11 November 2003

Abstract Four types of Altamura bread, obtained by using semolina from four pure durum wheat cultivars (Appulo, Arcangelo, Duilio and Simeto), were prepared and compared to evaluate the influence of durum wheat cultivar on the sensory properties and staling rate of the final product. Pure semolina samples showed marked differences in chemical and rheological properties, with semolina from cv. Simeto characterised by higher protein content, alveograph data (tenacity/extensibility ratio and deformation energy) and rate of hydration at the farinograph test. The durum wheat cultivar seemed to significantly affect staling rate, as determined by crumb water loss and firming, the bread from cv. Simeto showing a markedly lower crumb moisture loss and firming than the other breads during 8 days of storage. On the other hand, the sensory profile of bread was scarcely affected by durum wheat cultivar; among the 19 sensory descriptors defined to describe differences between bread samples, only crumb colour, grain and humidity, and crust crispness showed significant differences.

Keywords Bread · Durum wheat · Rheological properties · Sensory attributes · Staling

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Introduction

In the Mediterranean area, and particularly in southern Italy, durum wheat is used in the formulation of other products besides alimentary pasta, including several types of bread. *Pane di Altamura* is one of the most widespread of these types of bread and is at present the object of a request of recognition by the Protected Denomination of Origin [1]. This kind of bread is obtained from re-milled semolina of certain durum wheat cultivars (Arcangelo, Appulo, Duilio and Simeto, to be used on their own or in combination, and making up at least 80% of the total semolina, the remainder being made up of other cultivars) grown in the area of Altamura, a town in the Italian region Apulia, and by using the traditional baking method, which involves a prolonged sponge-dough procedure and the use of sourdough starter for leavening [2]. The main quality attributes of Altamura bread are its typical organoleptic properties and the long shelf life.

The sensory characteristics of white bread have been thoroughly investigated by various authors [3] and, in particular, several papers have dealt with the characterisation of the sensory profile of wheat sourdough bread [4]. The use of sourdough has been reported to produce breads characterised by a more intense flavour, and also to improve rheology and storage properties over breads obtained using baker's yeast [5]. On the other hand, little research has focused on the sensory attributes of durum wheat bread [6, 7].

As regards keeping properties, it has been reported that bread obtained from durum wheat flours is characterised by relatively slow staling and, consequently, a long shelf life [2], due to the high water-binding capacity of durum wheat flour [6]. The addition of durum wheat flours has been found to be useful in improving the breadmaking properties of poor quality common soft wheat and in extending the shelf life of the corresponding product, by using both a sponge-dough [8] and a straight-dough [9] breadmaking method, the sponge-dough procedure providing better results than the straight-dough. Moreover, Pasqui et al. [10] reported that 100% durum wheat bread, obtained by an experimental straight-dough baking method, was characterised by softer crumb and lower firming rate than soft wheat bread, and also observed a significant effect of durum wheat cultivar on crumb softness 24 h after baking.

Besides fermentation and baking operations, the characteristics of wheat flour can significantly affect the overall quality of bread. Several studies have investigated the breadmaking characteristics of durum wheat flours obtained from different cultivars and of different milling conditions, indicating significant differences in technological quality among cultivars [11].

The present study aimed to investigate the effect of the durum wheat cultivar on the sensory properties and staling rate of Altamura bread. To this purpose four types of Altamura bread, obtained by using semolina from four pure durum wheat cultivars, Appulo, Arcangelo, Duilio and Simeto, while keeping unchanged the other factors of the breadmaking process, were prepared and compared.

Materials and methods

Samples

Durum wheat grain (*Triticum turgidum* L. ssp. *turgidum* var. *durum*) for the cultivars Appulo, Arcangelo, Duilio and Simeto (20 kg each), all grown in Apulia (southern Italy), productions 1998/1999, and purchased by local seed companies, were milled in the laboratory by a MLU202 mill (Buhler, Uzwil, Switzerland) to obtain a re-milled semolina having the particle size distribution usually adopted for Altamura breadmaking. From each of the four types of semolina were prepared ten 1-kg loaves of Altamura bread, at a local bread-maker in Altamura (Bari, Italy), following the official recipe [1] consisting of a traditional baking method, which involves a prolonged sponge-dough procedure and the use of sourdough starter for leavening. The composition of the mix was 20% leaven (20 kg for 100 kg durum wheat flour), 2% sea salt and approximately 60% water (60 l for 100 kg durum wheat flour). The leaven is made by adding ingredients at least three times to increase the fermenting dough, i.e. water and durum wheat meal. All the samples were prepared during a single breadmaking process.

Analyses of re-milled semolina

Protein content (N×5.7) was determined according to the AACC approved method 46-11A [12]. Gluten index was determined as in AACC method 38-12A [12]. Sedimentation volume in sodium dodecyl sulphate was analysed following the indications reported by Dick and Quick [13]. Alveograph analysis was adapted to durum wheat as reported by D'Egidio et al. [14] and performed by a Chopin alveograph (Chopin, Villeneuve La Garenne, France). The farinograph test was carried out using a Brabender farinograph (Brabender, South Hackensack, N.J., USA) according to the AACC method 54-21 [12]. Water farinograph absorption (A), dough development time (B), dough stability (CD), and drop off of consistency after 12 min (E12) were measured. Yellow index was determined by the Chromameter CR200 tristimulus colorimeter (Minolta, Osaka, Japan), considering the b* value. All analyses were carried out in triplicate.

Analyses of bread

Sensory properties. Bread samples obtained from pure wheat varieties were evaluated and compared by quantitative descriptive analysis [15]. Twelve professional panellists, of the trained staff at INRAN (Istituto Nazionale di Ricerca per gli Alimenti e la Nutrizione, Roma, Italy), profiled the bread samples. They had been selected for their reliability, consistency and discriminating ability [16, 17] and trained in the sensory analysis lexicon and methodology, and had former experience in assessing bread samples. The experiment was designed so that two replicates were obtained for each type of bread. Samples were presented as slices 1-cm high, in coded dishes, and evaluated at random in two testing sessions. The list of sensory terms included 19 descriptors chosen by the assessors to describe differences between the bread samples. The descriptors were rated on an anchored line scale that provided a 0–9 score range, the anchor points being described in Table 2.

A two-way analysis of variance, with durum wheat cultivar and replicates as fixed effects and their interactions was performed in order to have an indication of the data variability. The mean values of the samples for each descriptive variable were compared between durum wheat cultivars by a multiple comparison Duncan test to look for grouping (at P=0.05).

Keeping properties. The staling rate of bread samples was evaluated by determining both crumb moisture content and firmness 1, 3, 4 and 9 days after breadmaking. Bread was stored in perforated plastic bags at room temperature. Crumb moisture was evaluated according to the AACC method 44-15A [12]. Bread crumb was removed by cutting plugs from one center slice and from a slice at each end of the loaf. The moisture contents of the bread samples, including crust, were also determined: these ranged from 34.5% to 36.0%. Firmness of the bread samples was measured on a Instron Universal Testing Machine (Instron, High Wycombe, Bucks, England), according to the AACC approved method 74-09 [12]. Five slices of 25 mm height were obtained from the central part of each loaf. Firmness was the force required to compress each slice for 6.25 mm (25% compression). Analysis of variance and Duncan test was performed to evince differences between types of bread and, for each type, between storage times.

Results and discussion

Properties of semolina

Table 1 reports chemical and rheological characteristics of re-milled semolina obtained from Appulo, Arcangelo, Duilio and Simeto durum wheat cultivars. A high protein content, a high alveograph deformation energy (W) and, above all, a low tenacity/extensibility ratio (P/L) value have been known to be required to obtain adequate loaf volume in most experiments; among farinograph data, a high dough development time, a high dough stability and a high water absorption are particularly important in breadmaking [11, 18, 19].

A considerable variability was observed between the four cultivars for each of the examined indices. The highest protein content was observed in Simeto, which showed also the smallest gluten, and was poorly extensible, with a gluten index value of 85 and a 66-mm high sediment in sodium dodecyl sulphate, while Arcangelo was characterised by the lowest values of both protein content, gluten index and height of sediment.

As for the alveograph data, P/L conspicuously varied between the four cultivars considered, but tenacity was always higher than extensibility, leading to P/L values greater than 1, as expected for durum wheat semolina [2]. For breadmaking purposes, the P/L ratio should not

Table 1 Chemical and rheological characteristics of re-milled semolina from the four durum wheat cultivars Appulo, Arcangelo, Duilio, Simeto, and results of the ANOVA at $P<0.05$

Determination	Durum wheat cultivar			
	Appulo	Arcangelo	Duilio	Simeto
Protein content (% dry wt)	12.6±0.3^{b}	9.9±0.3^{a}	12.6±0.3^{b}	13.3±0.3^{c}
Yellow index	17.8±0.3^{a}	19.0±0.4^{b}	18.6±0.3^{b}	20.1±0.2^{c}
Gluten index	50±5^{b}	40±3^{a}	70±5^{c}	85±5^{d}
Height of sediment in SDS (mm)	54±2^{b}	42±2^{a}	65±3^{c}	66±3^{c}
Alveograph data				
W (10^{-4} J)	84±5^{b}	71±3^{a}	144±6^{c}	220±7^{d}
P/L	1.57±0.03^{a}	2.02±0.06^{b}	3.08±0.07^{c}	5.03±0.10^{d}
Farinograph data				
Farinograph absorption (%)	59.4±1.9^{a}	59.0±1.8^{a}	58.5±1.8^{a}	63.7±1.9^{b}
Dough development time (min)	2.0±0.1^{b}	1.7±0.1^{a}	1.7±0.1^{a}	2.5±0.2^{c}
Dough stability (min)	2.3±0.1^{b}	2.0±0.1^{a}	2.0±0.1^{a}	5.5±0.2^{c}
Drop-off of consistency after 12 min (BU)	60±5^{b}	90±5^{c}	60±5^{b}	50±3^{a}

$^{a–d}$ Common superscripts in a row indicate no significant difference $P<0.05$
Protein content is calculated as N×5.7 and farinograph absorption calculation is based on a 14.0% moisture level. Drop-off consistency is expressed as Brabender units (*BU*)

exceed 2.00 with an optimum value ranging from 0.40 to 0.80 [9, 18, 20]. An extremely high value of P/L was found in Simeto (5.03), with an excessively high tenacity with respect to the extensibility; for Appulo a more equilibrated P/L ratio, of 1.57, was observed. Anyway, analyses carried out in the same period on commercial re-milled semolina blends currently used for Altamura breadmaking led to P/L values in the range 1.90–2.50, with W values ranging from 147×10^{-4} to 250×10^{-4} J. Values of P/L as high as those in Simeto are observed for durum wheat in certain years, especially in the Mediterranean climate, due to the effect of relatively high temperatures on gluten strength and tenacity, so that wheat produced in southern locations tends to have high alveograph P/L values [20]. In particular, in similar environments and in the same year, other authors also found P/L values of durum wheat semolina ranging from 1.05 to 8.53, with the highest value for the same cultivar, Simeto [21].

The work corresponding to the deformation of the dough (alveograph W) ranged from 71×10^{-4} J in Arcangelo to 220×10^{-4} J in Simeto, in accordance with the other indices of gluten quality determined. In soft wheat for breadmaking, corresponding to class 2 of the Italian quality marketing classification, W should be within the range 155×10^{-4}–180×10^{-4} J [20]. A prolonged sponge-dough procedure with sourdough for leavening, such as the case of Altamura bread, should require re-milled semolina with a W value as high as possible, that is a high gluten strength able to give a dough that can undergo a prolonged process without collapsing.

As for farinograph data, Simeto showed a higher water absorption than the other varieties, due to its higher protein content with respect to the other samples. In fact, besides protein quantity, the difference in the degree of damaged starch is the most likely factor to affect the rate of hydration [22], and a high degree of starch damage in the re-milled semolina of Arcangelo, with low protein content and gluten index but acceptably high water absorption, cannot be excluded. Consistent with its higher water absorption, Simeto showed a higher dough development time than the other cultivars. The higher protein content and tenacity also conferred a greater stability and a minor drop-off of consistency on the dough obtained from this cultivar with respect to the dough from Duilio, Appulo and especially Arcangelo, this last showing the highest drop in consistency, in accordance with its very low gluten index.

Also, the intensity of yellow colour of the re-milled semolinas was determined, because this attribute, due to the xantophyll pigment present in durum wheat kernels, may influence the colour of the final product and consequently consumer acceptability. Semolina from Simeto was found to have a more intense yellow colour, whereas the lowest yellow index was registered in the semolina from the Appulo cultivar.

Properties of bread

Sensory profile. The sensory profile of bread samples obtained from each of the four durum wheat cultivars was compared to evaluate the influence of cultivar on the organoleptic properties of bread. The sensory profile was established by evaluating the intensity of 19 sensory descriptors (Table 2) related to the characteristics of appearance, aroma, taste, flavour and texture of bread. A significant effect of replication was found only for humidity perceived at the surface of bread crumb and in no other attribute (Table 3), indicating a good reproducibility of results. A significant effect of the durum wheat cultivar was found for crumb grain and colour, as well as for crust crispness and humidity on the surface of bread crumb.

Average values for sensory attributes of the four bread samples are shown in Table 4. The yellow colour of the crumb (visual perception) was significantly more intense in Simeto, with Arcangelo, Duilio and Appulo following

Table 2 Descriptive terms used for sensory profiling of Altamura bread

	Descriptor	Definition	Scale anchors	
			Minimum (0)	Maximum (9)
External crumb appearance	Crumb colour	Colour intensity	Whitish	Light yellow
	Crumb grain	Cell structure of grain	Fine and uniform grain	Coarse and poorly homogeneous
Visual-tactile characteristics	Crust crispness	The way the crust fracture, when broken by fingers	Soft, it bends	Crisp, it breaks
	Crumb elasticity	Ability of the crumb to recover from compression exerted by fingers	Slow and partial recovery	Fast and complete recovery
Aroma attributes	Overall perception	The overall aromatics perception	Weak	Strong
	Bakery	The typical aroma of bread just taken out of the oven	Weak	Strong
	Sour	The aromatics associated with sour substances	None	Strong
	Semolina	The aromatics typical of semolina	None	Strong
	Yeasty	A fermented yeast-like aromatic	None	Strong
	Toasted	The aromatics associated with a toasted bread (evaluated on the crust)	None	Strong
Taste attributes	Sweet	A basic taste factor produced by sugars	None	Strong
	Salty	A basic taste factor produced by sodium chloride	None	Strong
	Sour	A basic taste factor produced by acids	None	Strong
	Bitter (aftertaste)	A basic taste factor produced by caffein	None	Strong
Flavour attributes	Overall perception	The overall retronasal perceptions	Weak	Strong
	Toasted	Typical flavour associated with a toasted bread (evaluated on the crust)	None	Strong
Texture attributes	Crust hardness	Force required to compress the product with the molars	Soft	Hard
	Humidity	Humidity perceived at the surface of bread crumb	Dry	Humid
	Cohesiveness of mass	The degree to which chewed sample holds together in a mass	Loose mass	Tight mass

Table 3 Effect of durum wheat cultivar and replicates, and their interactions, on sensory attributes

	Sensory attribute	*F* value		
		Durum wheat cultivar (*X*)	Replicate (*Y*)	(*X*×*Y*)
External crumb appearance	Crumb colour	6.4***	0.01	0.11
	Crumb grain	18.89***	0.01	0.18
Visual-tactile characteristics	Crust crispness	4.22**	0.58	0.42
	Crumb elasticity	1.38	0.61	0.27
Aroma attributes	Overall perception	1.44	0.00	0.18
	Bakery	0.06	0.63	0.41
	Sour	0.08	0.12	0.14
	Semolina	0.25	0.01	0.06
	Yeasty	1.77	0.09	0.07
	Toasted	1.77	3.11	0.84
Taste attributes	Sweet	0.50	0.23	0.10
	Salty	1.10	0.04	0.58
	Sour	0.32	0.04	0.47
	Bitter (aftertaste)	0.35	1.02	0.34
Flavour attributes	Overall perception	0.56	0.01	0.09
	Toasted	0.14	1.43	0.95
Texture attributes	Crust hardness	1.84	0.49	0.78
	Humidity	4.76***	4.76*	0.50
	Cohesiveness of mass	0.18	0.11	0.15

*$P<0.05$; **$P<0.01$; ***$P<0.001$

in decreasing order; a more richly yellow coloured crumb is a typical characteristic of bread obtained from durum wheat and plays a relevant role in determining consumer preference for this kind of product. The score for colour, determined by sensory analysis, was strongly correlated with the yellow index obtained by colorimetric determination on the four types of starting re-milled semolina ($r=0.97$, $P<0.01$). In general, the yellow pigments may undergo a partial oxidation during the various phases of breadmaking, particularly during kneading; nevertheless the observed correlation suggested that the starting differences of pigment content between the four semolina

Table 4 Mean values and standard deviations of sensory attributes of bread samples

	Sensory variables	Durum wheat cultivar			
		Appulo	Arcangelo	Duilio	Simeto
External crumb appearance	Crumb colour	6.3±0.87^{a}	7.0±0.90$^{b, c}$	6.8±0.72^{b}	7.3±0.68^{c}
	Crumb grain	3.8±0.99^{a}	5.6±0.96^{c}	3.8±0.94^{a}	4.9±0.98^{b}
Visual-tactile characteristics	Crust crispness	4.7±0.94^{b}	3.9±0.79^{a}	3.8±0.96^{a}	3.9±0.95^{a}
	Crumb elasticity	6.8±0.82	6.9±0.98	7.2±0.78	7.2±1.01
Aroma attributes	Overall perception	6.1±0.67^{a}	6.5±0.68^{b}	6.4±0.63$^{a, b}$	6.5±0.53^{b}
	Bakery	2.4±1.51	2.4±1.43	2.5±1.38	2.6±1.31
	Sour	1.6±1.59	1.5±1.61	1.7±1.38	1.7±1.60
	Semolina	4.5±1.57	4.4±1.40	4.6±1.66	4.8±1.62
	Yeasty	1.7±1.11	1.0±0.96	1.5±1.43	1.2±1.07
	Toasted	2.6±1.72	3.5±1.49	2.9±1.96	3.0±1.71
Taste attributes	Sweet	3.1±1.35	3.2±1.26	3.3±1.43	3.5±1.18
	Salty	4.2±1.03	4.3±1.16	4.3±1.06	3.8±1.06
	Sour	1.6±1.47	1.3±1.42	1.4±1.43	1.2±1.36
	Bitter (aftertaste)	1.1±1.17	1.4±1.40	1.1±1.37	1.3±1.22
Flavour attributes	Overall perception	5.8±0.72	5.9±0.73	6.0±0.56	6.0±0.55
	Toasted	2.9±2.18	3.2±1.96	3.2±2.24	3.2±1.95
Texture attributes	Crust hardness	4.7±0.96	4.7±0.81	5.2±0.91	5.1±0.90
	Humidity	5.9±0.77^{a}	6.6±0.93^{b}	6.3±0.56$^{a, b}$	6.6±0.58^{b}
	Cohesiveness of mass	5.3±1.12	5.4±1.33	5.3±1.11	5.1±1.55

$^{a–c}$ Common superscripts in a row indicate no significant difference P<0.05

Table 5 Moisture content of crumb samples from different types of bread at increasing storage times

Days of storage	Moisture content (%)				
	Appulo	Arcangelo	Duilio	Simeto	F values
1	^{c}44.6±0.2^{a}	^{c}46.4±0.2^{b}	^{c}46.1±0.2^{b}	^{b}46.3±0.2^{b}	53.25***
3	^{b}40.4±0.7^{a}	^{b}41.7±0.2^{b}	^{b}42.6±0.3^{c}	^{a}41.2±0.9^{b}	15.44**
9	^{a}33.9±0.9^{a}	^{a}37.5±0.9^{b}	^{a}39.4±0.2^{c}	^{a}42.7±0.7^{d}	75.44***
F values	195.20***	200.46***	594.53***	108.47***	
Δ/day	1.3	1.1	0.8	0.4	

$^{a–d}$ Different superscript letters preceding numbers indicate significant differences between values within each column, according to the Duncan test (P=0.05). Different superscript letters following numbers indicate significant differences between values within each row
*P<0.05; **P<0.01; ***P<0.001

types were preserved during the process of Altamura breadmaking.

Humidity values as perceived by the assessors on the surface of bread significantly correlated with crumb humidity values (Table 5) determined by weight loss in oven (r=0.94, P<0.02), whereas they did not show significant correlation to dough water absorption (r=0.42), so the extent of water absorption during kneading did not seem to reflect on the water content of the final product 24 h after baking. Moreover, humidity perceived on the surface of bread crumb was lower in bread from Appulo, whose crust, on the other hand, appeared more crisp than in the other bread types. In cereal products having a moisture content above 10%, as well as in bread crust, decreasing moisture levels have been associated with increasing crispness [23, 24], so the higher crispness observed on the crust of bread from Appulo denoted its lower moisture content, that in turn paralleled the lower humidity perceived on its crumb. On the other hand, this lower humidity might contribute to a slightly less intense overall aroma with respect to the other samples.

Breads also differed for crumb grain, with samples from Appulo and Duilio cultivars showing a more fine and uniform crumb grain. In general durum wheat bread is characterised by a fine, dense crumb structure, partly due to the marked tenacity and the poor extensibility of the dough obtained from semolina. Moreover, high levels of sourdough have been associated with a denser crumb structure [23]. In our experiment, the crumb grain score was not clearly related to the viscoelastic properties of the gluten, measured as gluten index or P/L, and it is probable that other factors, for example different lengths of time required for crust formation and pressure in the dough resulting from crust formation, played a more relevant role in determining these differences [25].

No significant differences were found in the other sensory descriptors, particularly those related to aroma, taste and flavour, probably due to the absence of differences among bread samples in the leavening and baking process, main factors in determining bread aroma and taste attributes [4].

Table 6 Firmness values of bread samples at different storage times

Days of storage	Firmness (N)				*F* values
	Appulo	Arcangelo	Duilio	Simeto	
1	$^{a}11.0{\pm}1.6^{b}$	$^{a}7.2{\pm}2.4^{a}$	$^{a}7.6{\pm}1.4^{a}$	$^{a}10.7{\pm}0.9^{b}$	5.78^{*}
3	$^{a,\,b}17.3{\pm}3.1^{a}$	$^{b}14.5{\pm}1.4^{a}$	$^{b}18.3{\pm}3.3^{a}$	$^{a}14.4{\pm}2.3^{a}$	2.25
4	$^{b}20.7{\pm}3.2^{b}$	$^{c}21.1{\pm}3.2^{b}$	$^{b}24.9{\pm}4.0^{b}$	$^{a}14.2{\pm}2.2^{a}$	7.63^{**}
9	$^{c}48.0{\pm}10.2^{b}$	$^{d}35.3{\pm}6.9^{b}$	$^{c}41.8{\pm}8.8^{b}$	$^{b}21.5{\pm}4.0^{a}$	8.40^{**}
F values	33.76^{***}	35.37^{***}	30.92^{***}	12.19^{***}	
Δ/day	4.6	3.5	4.3	1.3	

$^{a\text{–}d}$ Different superscript letters preceding numbers, indicate significant differences between values within each column, according to the Duncan test (P=0.05). Different superscript letters following numbers, indicate significant differences between values within each row
$^{*}P<0.05$; $^{**}P<0.01$; $^{***}P<0.001$

Keeping properties. A strong negative correlation between consumer acceptability and crumb compressibility or firmness has been well documented [26]. Moreover the staling of bread is normally perceived by consumers as involving a discernible drying out of the crumb, and higher moisture contents are associated with more crumb freshness. Therefore, in order to evaluate the influence of durum wheat cultivar on keeping properties of bread, the bread samples were stored for up to 9 days after baking and the extent of staling was determined by measuring both crumb firmness and moisture content.

As expected, all bread samples showed a definite decrease in crumb moisture content during 8 days of storage (Table 5), but significant differences among bread types were observed in the rate of crumb moisture loss. At day 1, breads from Arcangelo, Duilio and Simeto were characterized by similar moisture contents, with the bread from Appulo showing a slightly lower value. During the first 3 days of storage all bread types showed similar changes in water content (approximately, a 10% decrease in the moisture content registered at the beginning of the experiment). In contrast, during the following days crumb moisture content remained practically unchanged in the bread from Simeto, whereas it continued to decrease in the other breads; consequently at the end of the considered storage period the bread from Simeto was characterised by a significantly higher moisture content than the other types, having shown quite a smaller change per day.

Table 6 reports data regarding crumb firmness. Twenty-four hours after baking, significant differences were found among samples, with breads from Arcangelo and Duilio showing softer crumb than the others. During the following days of storage the bread from Simeto was characterised by a markedly low firming rate: during 8 days of storage it showed a change in firmness per day of 1.3 N, whereas breads from Appulo, Duilio and Arcangelo showed changes per day of 4.6, 4.3 and 3.5 N, respectively. In particular, the bread from Simeto, unlike the other types, did not show any significant firmness increase till day 4, and beginning from the 4th day it was significantly and markedly softer than the other breads.

According to the observation of Rogers et al. [27], the rate of firming is a function of bread (including crust) moisture content, at up to 37% water content: as bread moisture decreases, the rate of firming increases. On the other hand in our experiment firming rate was not significantly correlated with bread moisture content determined 24 h after baking (either including crust—data not reported—or not), even though the lowest firming rate was observed in the bread (from cv. Simeto) characterised by the most effective moisture retention during the entire storage period. Moreover, the dough obtained from the semolina of Simeto showed a significantly higher rate of hydration in the farinograph test than the doughs from the other semolinas, and farinograph absorption values results inversely correlated with the change in firmness per day (r=–0.93; P<0.05), suggesting that the same factors that improved dough water absorption capacity, could contribute to slowing down the firming process of crumb.

Studies on the effect of flour quality on the staling rate of bread have focused attention on protein content and quality [26]. Kim and D'Appolonia [28] observed a reduction in the staling rate of bread with increasing protein contents, and attributed this effect to the dilution of starch by the higher protein levels. Nevertheless, differences in firming rate in our samples did not seem to be significantly related to different protein contents (data on bread protein content, not reported, paralleled those on semolina samples).

On the other hand, a relevant effect exerted by gluten quality on bread keeping properties has been proposed by various authors. Maleki et al. [29] and Martin et al. [30] observed different staling rates in breads obtained from different wheat cultivars and concluded that the quality of gluten was the major factor responsible for the differences in staling rate.

So, even though a detailed discussion of the relationships between gluten properties and the firming process is far beyond the scope of this work, the possibility that the quite different gluten properties of the starting semolinas, denoted by the marked variability observed in rheological characteristics, had significantly affected the firming rate cannot be ruled out, especially considering that Simeto bread derived from semolina with the gluten of the highest quality.

In conclusion, Altamura breads obtained by using semolina from four distinct pure durum wheat cultivars, characterised by markedly different rheological properties, showed significantly different staling rates, and minor differences in the sensory profile. Different factors may contribute to the relatively slow staling rate of Altamura bread: the acidification produced by sourdough [5] as well as the prolonged sponge-dough method [9]. Our results showed that, in addition to these factors, durum wheat cultivar may significantly influence the staling rate of the final product due to differences in protein quantity and quality, that, in turn, may result in doughs with different rates of hydration, and in breads characterised by significantly different rates of water loss and firming.

This means that a careful combination of the four cultivars specified in the official recipe [1] and the addition of other selected cultivars (up to a maximum of 20%), could further improve the keeping properties of the final product, providing, at the same time, an adequate balance of the rheological properties of the dough.

Acknowledgements We are indebted to Mr. Giuseppe Barile for accurate breadmaking, and to Tiziana Catone, Elisabetta Moneta and Nicoletta Nardo for technical assistance. The authors equally contributed to the realisation of this work.

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