Optimization of durum wheat bread from a selenium-rich cultivar fortified with bran

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Abstract In this work the effect of bran addition (5 %, 10 %, 15 %, 20 %, 25 %, 30 %) on sensory, nutritional and mechanical properties of bread made from a durum wheat semolina enriched with selenium (cultivar PR22D89) was addressed; traditional and whole-meal bread from the same cultivar PR22D89, without any further bran addition, were also investigated for comparative purpose. In order to improve the durum wheat functional bread, different structuring agents (agar agar, gellan gum, guar seed flour, hydroxy-propyl-cellulose, modified food starch-CAPSUL[®] and tapioca starch) were firstly screened and then optimized. Sensory, textural and nutritional properties of bread were studied in each step. Results showed that bread from PR22D89 cultivar with addition of bran up to 30 % was completely accepted from the textural, nutritional and sensory points of view with proper utilization of guar seed flour or modified food-starch (2 %).

Keywords Functional bread · Bran · Selenium · Hydrocolloids · Nutritional properties

Introduction

Bread is a food product obtained by fermentation, leavening and subsequent baking of dough made from cereal flour,

yeast, water, often enriched and characterized by regional ingredients. It has a fundamental place in the human diet, known since the beginning of civilization. In ancient Egypt wheat grains were crushed, the powder obtained was mixed with water and the dough was left untouched to be cooked the next day. To date the method of milling grain has evolved, leading to the modern mills, based on separating the endosperm (which produces refined white flour when milled) from the germ and the bran. However, in terms of health, this separation is not positive and several studies suggest that the whole-wheat flour is better than the white flour: the regular consuming of whole-grain foods can reduce the risks of several form of cancer, coronary heart disease rates and helps to regulate blood glucose level (Gil et al. 2011). In particular, wheat bran presents health benefits in terms of cardiovascular disease, colon cancer, obesity and gastrointestinal diseases prevention (Stevenson et al. 2012). Unfortunately, the majority of consumers prefer bakery products produced from refined white flour to whole grain products, which in general has a lower volume and coarser texture than the traditional.

The replacement of refined flour with variable percentages of bran is the current technology to obtain an increase of bioactive compounds in wheat flour and their derivative products. Nevertheless, bran addition to bread formulation causes a reduction of loaf characteristics, such as lower volume, darker crust and denser crumb texture than the traditional products (Blandino et al. 2013; Schmiele et al. 2012). The literature studies conducted on the effects of bran addition highlight that bread final characteristics strictly depend on the properties of the wheat cultivars and particle size (Sidhu et al. 1999; Seyer and Gélina 2009; Schmiele et al. 2012). Therefore, proper cultivar selection is of crucial importance for bread quality. As a fact, since the beginning of twentieth century, to optimize the production of cereals food, Italian farmers have developed a selection of cultivars. Indeed, durum wheat was object of

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intensive breeding programs aimed to develop modern cultivars able to satisfy the requirements of intensive agricultural systems and industrial quality standards (Piergiovanni 2013). Furthermore, to produce wheat varieties with high nutritional value, researchers developed the landraces enriched of essential mineral elements, such as zinc, iron or selenium (Velu et al. 2012). Following this trend, a new durum wheat cultivar (PR22D89) was developed by the CRA-CER center of Foggia, registered in the national register of wheat variety since 2005 and marketed across Europe (Ficco et al. 2011). It is a cultivar with a high productive potential, from which grain semolina with high protein content and excellent gluten quality is obtained. Moreover, this cultivar has been enriched in selenium, as result of a subsequent fertilization program, aimed to further increase the nutritional value. Selenium (Se) is an essential element for human dietary: an insufficient Se supply is associated to a reduction of fertility, oxidative stress-related disorders and impaired immune function (Rayman 2008). It is known that the human selenium intake is determined by the food Se composition. Cereals, bread and meat and fish products contributing more than 50 % of total intake, corresponding to $28 \mu\text{g Se d}^{-1}$ (Broadley et al. 2010). The Dietary Reference Intakes for Selenium (National Research Council 2000) is $15\text{--}20 \mu\text{g d}^{-1}$ for infants, $20\text{--}30 \mu\text{g d}^{-1}$ for children and $40\text{--}55 \mu\text{g d}^{-1}$ for adults, with the exception of pregnancy and lactation, where the levels are respectively 60 and $70 \mu\text{g d}^{-1}$.

Based on what has been reported beforehand, the aim of this study was to determine the effects of bran addition to a specific wheat cultivar rich in selenium (PR22D89). Different structuring agents were also optimized to improve the sensory quality of the functional bread.

Materials and methods

Raw materials

One of the most representative Italian durum wheat cultivars PR22D89 (*Triticum durum* Desf.), released on 2005, was selected for a foliar application trial using two rates of sodium selenate (Na_2SeO_4): 0 g/ha Se (Se^-) and 120 g/ha in elemental Se (Se^+). Durum wheat crop was sown in the experimental field of the Consiglio per la Ricerca e la Sperimentazione in Agricoltura (CRA), Centro di Ricerca per la Cerealicoltura (CER) of Foggia during 2011–2012 growing season in plots arranged in a randomized blocks with three replications. Selenium foliar application was carried out at the end of booting stage when the first awns were visible (Zadoks scale 49; Zadoks et al. 1974). The sowing date was 12 December 2011 and the material was harvested on 15 June 2012. Seed tempered to 16.5 % moisture were milled on experimental mill with three breaking and three sizing passages

(Labormill, BONA, Monza, Italy) to obtain durum wheat semolina. An experimental stone mill (Mod MB250 Partisani) was adopted to obtain the whole-meal durum wheat semolina. Whole kernels were milled on a TecatorCyclotec 1093 (International PBI, Milano, Italy) laboratory mill (1 mm screen-60 mesh).

Fresh compressed yeast, salt and extra virgin olive oil to produce bread were bought from a local market. The agar agar, gellan gum, guar seed flour, hydroxy-propyl-cellulose and tapioca starch as structuring agents were bought from Farmalabor s.r.l. (Canosa di Puglia, Italy). The modified food starch-CAPSUL® (derived from waxy maize) was kindly provided by National Starch (Bridgewater, U.S.A.).

Bread-making process

Dough mixing, proofing and baking were performed by means of laboratory-scale equipments. A straight dough process was used. Dough based on 100 % durum wheat (named CTRL-C) and 100 % whole-meal durum wheat (named as CTRL-W) both from cultivar PR22D89 were prepared using the following formulation: 2000 g of durum wheat semolina or whole-meal durum wheat semolina, 60 g of compressed yeast, 60 g of salt, 40 g of extra virgin olive oil and 1250 mL of water for CTRL-C or 1500 mL for CTRL-W. Dough were obtained by mixing the flour with water and salt in a mixer (Conti kneaders, Verona, Italy); then, all the other ingredients were slowly added and mixed together in a first step at low speed (4 rpm) for 15 min and in a second step at high speed (120 rpm) for other 5 min. Afterwards, the obtained dough were weighted (two dough pieces each of 1500 g), manually rounded and placed in a thermostatically controlled proofing oven (Thermogel, Varese, Italy) at constant temperature (30°C) and relative humidity (85 %). The functional bread was prepared with the same procedure used for the control samples with the addition of different bran amounts (5, 10, 15, 20, 25 and 30 %) during the mixing process. The amount of water for each dough sample was determined by a preliminary trial of water absorption.

In a subsequent experimental trial, in order to improve the organoleptic quality of the functional bread, different structuring agents were used. According to a previous work (Mastromatteo et al. 2012a), each structuring agent at a concentration of 2 % was first dissolved in water (at about 100°C) prior to the mixing with the other ingredients. In particular, agar agar (AG), gellan gum (GG), guar seed flour (GUA), hydroxy-propyl-cellulose (HPC), modified food-starch CAPSUL® (STC) and tapioca starch (TAP) were used. Then, the two structuring agents selected were varied (1 %, 2 %, 3 %) to individuate the optimal concentration to be added. Also for these last trials, the water amount for each dough sample was determined by a preliminary trial of water absorption.

Moreover, each dough required different leavening times (Table 1) after which dough was baked for 55 min in a preheated electric oven (Europa Forni, Vicenza, Italy) at 250 °C. Samples were left to cool at ambient temperature for about 2 h and then analyzed. Baking process was performed in triplicate. All the bread samples investigated are listed in Table 1.

Nutritional properties

Chemical composition of bread samples was performed by determining proteins, fat, ash, total dietary fiber (TDF), soluble and insoluble dietary fibers (SDF and IDF, respectively) content. To the aim, dry samples were ground to fine flour on a Tecator Cyclotec 1093 (International PBI, Milano, Italy) laboratory mill (1 mm screen – 60 mesh). Protein content (%N × 5.7) was analysed with the micro Kjeldahl method, according to the Approved Method 46-13 (American Association of Cereal Chemists 2000b). Total dietary fibre (TDF), soluble-water fibre (SDF) and insoluble-water fibre (IDF) contents were determined by means of the Total Dietary Fibre Kit (Megazyme), based on an enzymatic gravimetric procedure of the AACC Method 32-07 (AACC International 2000).

Ash content was determined by standard method 08-01 (American Association of Cereal Chemists 2000a) on milled grain. Crude fat contents were determined by AOAC Method 2003.05 (AOAC International 2006). The selenium content was determined by mass spectrometry (ICP-MS) using the isotope ⁸⁰Se. All chemical analyses were made in triplicate.

Mechanical properties

Dough tensile properties

The tensile properties of dough were measured by using a Texture Analyzer Zwick/Roell model Z010 (ZwickRoell Italia S.r.l., Genova, Italia) equipped with a dough tensile testing device. The specimen preparation and trial specifications were carried out as reported by Mastromatteo et al. (2012b).

Crumb texture analysis

All bread loaves were uniformly sliced (slice thickness 15 mm) and crust was cut off, to allow crumb texture measurement. Cylindrical crumb samples of 28 mm diameter were

Table 1 Formulations of the investigated bread samples

Samples	Code	Conventional/ Wholemeal/ semolina (g)	Bran (g)	Structuring agent (g)	Total water content (mL)	Proofing time (min)
CTRL-CONVENTIONAL	CTRL-C	2000	–	–	1250	45
CTRL-WHOLEMEAL	CTRL-W	2000	–	–	1500	60
Conventional semolina +5 % Bran	5%Br	1900	100	–	1400	30
Conventional semolina +10 % Bran	10%Br	1800	200	–	1450	30
Conventional semolina +15 % Bran	15%Br	1700	300	–	1500	40
Conventional semolina +20 % Bran	20%Br	1600	400	–	1550	40
Conventional semolina +25 % Bran	25%Br	1500	500	–	1550	60
Conventional semolina +30 % Bran	30%Br	1400	600	–	1600	60
Conventional semolina +30 % Bran +2 % AGAR	2%AG	1400	600	40	1650	45
Conventional semolina +30 % Bran +2 % GELLAN GUM	2%GG	1400	600	40	1800	45
Conventional semolina +30 % Bran +1 % GUAR	1%GU	1400	600	20	1600	50
Conventional semolina +30 % Bran +2 % GUAR	2%GU	1400	600	40	1750	45
Conventional semolina +30 % Bran +3 % GUAR	3%GU	1400	600	60	1800	45
Conventional semolina +30 % Bran +2 % HPC	2%HPC	1400	600	40	1600	60
Conventional semolina +30 % Bran +1 % MODIF. STARCH	1%STC	1400	600	20	1500	40
Conventional semolina +30 % Bran +2 % MODIF. STARCH	2%STC	1400	600	40	1500	40
Conventional semolina +30 % Bran +3 % MODIF. STARCH	3%STC	1400	600	60	1500	45
Conventional semolina +30 % Bran +1 % TAPIOCA STARCH	2%TAP	1400	600	40	1600	60

cut from the centre of each bread loaf using a circular cutter. Compression tests were carried out by means of a Texture Analyzer Zwick/Roell model Z010 (ZwickRoell Italia S.r.l., Genova, Italia). The methodology used and the experimental conditions were according to Mastromatteo et al. (2013).

Sensory analysis

Ten trained tasters (four men and six women, aged between 28 and 45) were used to evaluate the sensory attributes of bread samples. They were trained in the sensory analysis, lexicon and methodology. Each slice of bread was placed on a white plate and identified with a random three-digit number. Attributes such as color, appearance, crust and crumb firmness, large bubbles and overall quality were evaluated by using a 9-point scale where 1 corresponded to “extremely unpleasant”, 9 to “extremely pleasant” and 5 represented the acceptability threshold (Mastromatteo et al. 2012a, b).

Statistical analysis

The experimental data were subjected to statistical evaluation using a one-way variance analysis (ANOVA). Duncan’s multiple range tests were used to determine the difference among means and the significance was defined at $p < 0.05$. To this aim a STATISTICA 7.1 for Windows (StatSoft, Inc., Tulsa, OK, USA) was used. Moreover, the interactions between textural, sensory and nutritional parameters of bread were evaluated using a correlation matrix.

Results and discussion

In order to obtain bread with a good balance between sensory and nutritional properties, the work was organized in two subsequent experimental steps. In the first one the percentage of bran was increased until reaching the sensory acceptability threshold, whereas in the second step various structuring agents were screened to improve the organoleptic properties of the functional bread obtained in the first step.

Step 1: effect of bran addition

As reported, bran was incorporated in different amounts (5, 10, 15, 20, 25 and 30 %) into durum wheat semolina. The impact of this substitution on nutritional, sensory and textural characteristics of bread was examined and compared with proper control samples.

Table 2 shows the results of the nutritional parameters and the sensory evaluation of bread samples. As regard the nutritional properties, contents of fat, proteins, ash, dietary fibers (soluble, insoluble and total) and selenium were different among samples, thus reflecting the different formulation of

bread recipes. As expected, milling technique caused a different chemical composition of the two control samples, giving the CTRL-W as the bread with the highest score of nutritional parameters. Indeed, during the traditional milling process a separation of endosperm from the germ and the bran was carried out, thus provoking the loss of fibers, proteins and minerals. Instead, flours obtained by a grinding stone generally contain all part of the grain and present high nutritional value (Schmiele et al. 2012). Regarding the minerals content, Cubadda et al. (2009) showed that the milling process significantly reduced the concentrations of all minerals in durum wheat, with average losses ranging from 16 % for selenium to 66 % for magnesium and zinc on a dry weight basis. Therefore, the use of cultivars rich in such mineral contents is more than desirable (Broadley et al. 2010). As regard the samples realized with bran addition, the fortification of dough with 30 % allowed realizing bread with very good nutritional properties (Banu et al. 2012; Schmiele et al. 2012); in particular, a high selenium content was recorded (5.79 ppm), also better than the CTRL-W sample (4.92 ppm), thus suggesting that proper bran addition, better than the simple stone milling, allows giving very good fortified bread.

Contrary to the beneficial effects recorded in the nutritional composition, a substantial decrease in bread acceptability was recorded with the highest bran addition. In particular, the overall quality declined from value less more than 7 of the controls to 5 of the 15 %, 20 % and 25 % bran-added samples, thus remaining within the sensory threshold (score = 5). On the contrary, the overall quality declined from 7.5 to about 4 in the highest bran-enriched bread, due to great defects in crumb firmness and lack of large bubbles. This result is a consequence of the gluten dilution with fibers addition that changed gluten network and decreased baking quality (Banu et al. 2012; Sidhu et al. 1999; Rao and Rao 1991). Pomeranz et al. (1977) also demonstrated that low amount (7 %) of wheat bran did not significantly change the pan bread properties.

Results of sensory evaluation can be also justified with findings recorded from the mechanical characterization of dough and from the compression test carried out on the crumb (Table 3). As can be seen in the Table 3, the conventional dough is more elastic and tenacious with respect to the whole-meal dough. Comparing all the samples in terms of tenacity it can be noted that this parameter greatly increased with bran addition, moving from 3.54 Nmm for the CTRL-C to more than 6 Nmm for 5%Br, 10%Br and 15%Br. The value decreased when 20 % (4.72 Nmm), 25 % (4.40 Nmm) and 30 % (3.26 Nmm) of bran were utilized, thus demonstrating the complex interactions that occurred between bran, water and gluten matrix (Seyer and Gélinas 2009; Schmiele et al. 2012). The *Strain_{break}* value decreased with the increase of bran concentration

Table 2 Nutritional and sensory properties of bread samples investigated in the Step 1

	CTRL-W	CTRL-C	5%Br	10%Br	15%Br	20%Br	25%Br	30%Br
Nutritional properties								
Fat (%)	4.71 ^g ± 0.01	4.26 ^e ± 0.20	4.04 ^d ± 0.06	4.47 ^f ± 0.03	4.97 ^a ± 0.01	5.04 ^{a,b} ± 0.06	5.16 ^{b,c} ± 0.08	5.28 ^c ± 0.01
Protein (%)	15.88 ^a ± 0.07	14.99 ^b ± 0.01	15.20 ^c ± 0.01	15.47 ^d ± 0.01	15.67 ^f ± 0.00	15.57 ^e ± 0.01	15.91 ^a ± 0.06	16.06 ^g ± 0.03
Ash (%)	4.40 ^a ± 0.02	3.47 ^b ± 0.18	4.04 ^c ± 0.03	4.18 ^d ± 0.01	4.38 ^a ± 0.01	4.42 ^a ± 0.03	4.59 ^c ± 0.01	4.75 ^f ± 0.03
TDF (%w/w)	15.96 ^a ± 0.53	10.05 ^b ± 1.22	11.43 ^c ± 0.00	14.87 ^d ± 0.23	17.01 ^a ± 0.00	18.35 ^e ± 1.00	19.60 ^f ± 0.35	22.42 ^g ± 0.21
IDF (%w/w)	12.01 ^a ± 0.96	7.22 ^c ± 1.13	8.95 ^d ± 0.00	11.83 ^a ± 0.53	13.24 ^e ± 0.00	14.99 ^b ± 0.75	15.66 ^b ± 0.21	17.85 ^f ± 0.07
SDF (%w/w)	3.95 ^a ± 0.43	2.83 ^{b,c} ± 0.09	2.48 ^b ± 0.00	3.04 ^{c,d} ± 0.30	3.77 ^a ± 0.00	3.36 ^d ± 0.25	3.94 ^a ± 0.14	4.57 ^e ± 0.28
Selenium (ppm)	4.92 ^{a,b} ± 0.04	3.98 ^c ± 0.18	4.52 ^d ± 0.06	4.82 ^a ± 0.06	5.05 ^b ± 0.08	5.28 ^e ± 0.06	5.55 ^f ± 0.07	5.79 ^g ± 0.03
Sensory characteristics								
Color	7.00 ^{a,b} ± 0.00	7.50 ^c ± 0.00	7.25 ^b ± 0.27	7.00 ^{a,b} ± 0.00	7.00 ^{a,b} ± 0.00	6.88 ^a ± 0.25	7.00 ^{a,b} ± 0.00	7.00 ^{a,b} ± 0.00
Appearance	7.00 ^b ± 0.00	7.50 ^e ± 0.00	6.75 ^b ± 0.27	6.25 ^d ± 0.29	5.75 ^a ± 0.29	5.38 ^a ± 0.25	5.75 ^a ± 0.29	4.75 ^c ± 0.29
Crust firmness	6.30 ^{a,b} ± 0.27	7.50 ^d ± 0.00	6.50 ^{b,c} ± 0.00	6.75 ^c ± 0.29	6.25 ^{a,b} ± 0.29	6.25 ^{a,b} ± 0.29	6.00 ^a ± 0.00	6.00 ^a ± 0.00
Crumb firmness	7.30 ^c ± 0.27	7.50 ^c ± 0.41	6.50 ^d ± 0.00	5.88 ^b ± 0.25	5.00 ^a ± 0.00	5.00 ^a ± 0.00	5.75 ^b ± 0.29	4.75 ^a ± 0.29
Large bubbles	7.20 ^c ± 0.27	7.50 ^f ± 0.00	6.50 ^d ± 0.00	6.00 ^c ± 0.00	5.00 ^a ± 0.00	5.00 ^a ± 0.00	5.00 ^a ± 0.00	4.25 ^b ± 0.29
Overall quality	7.30 ^c ± 0.27	7.50 ^c ± 0.41	6.50 ^b ± 0.00	6.25 ^b ± 0.29	5.00 ^a ± 0.00	5.00 ^a ± 0.00	5.00 ^a ± 0.00	4.25 ^d ± 0.29

In sensorial analysis, each descriptor was evaluated on a 0 to 9 scale

^{a-c} Means in the same row followed by different superscript letters differ significantly ($p < 0.05$)

because bran acts as trigger point of the dough fracture; therefore, the greater the amount of bran the easier the dough breaks (Banu et al. 2012). Data of crumb compression also highlight that bread with 100 % conventional semolina enriched with selenium shows the softest crumb and the increase of bran concentration caused an increase of crumb firmness, even if there are no significant differences when bran concentration exceed 20 %. To sum up, bread with 30 % of bran was selected for the most interesting nutritional content but further technological options were needed to make the product acceptable from the other points of view. For this reason, hydrocolloids were adopted in subsequent trials. Results of Step 2 are reported below.

Step 2: optimization of functional bread with structuring agents

In the second experimental step different structuring agents were added to the formulation at 2 % of concentration to improve the overall quality of the bread enriched with 30 % of bran. As stated above, agar agar (AG), gellan gum (GG), guar seed flour (GU), hydroxy-propyl-cellulose (HPC), modified food starch-Capsul® (STC) and tapioca starch (TAP) were tested. Then, the best two structuring agents were also tested at other concentrations to find the most appropriate to be used.

In Table 4 the effects of the structuring agents on the sensory evaluation of breads were reported. It can be noted that

Table 3 Textural properties of dough and crumb samples investigated in the Step 1

	Tension test				Compression test
	F_{max} (N)	Tenacity (Nmm)	F_{break} (N)	Strain _{break} (%)	* $F_{50\%}$ (N)
CTRL-W	0.18 ^b ± 0.02	3.24 ^a ± 0.50	0.09 ^b ± 0.01	27.86 ^b ± 1.59	8.91 ^e ± 0.84
CTRL-C	0.25 ^a ± 0.03	3.54 ^{a,c} ± 0.19	0.12 ^a ± 0.01	40.25 ^a ± 1.98	6.11 ^d ± 0.87
5%Br	0.32 ^c ± 0.03	6.87 ^b ± 0.59	0.16 ^c ± 0.02	34.51 ^c ± 1.71	12.95 ^b ± 1.01
10%Br	0.22 ^{a,b} ± 0.04	6.25 ^b ± 0.90	0.11 ^{a,b} ± 0.02	39.45 ^a ± 1.72	11.75 ^b ± 0.95
15%Br	0.24 ^a ± 0.02	6.11 ^b ± 0.51	0.12 ^a ± 0.01	37.56 ^a ± 1.86	15.99 ^c ± 0.88
20%Br	0.21 ^{a,b} ± 0.03	4.72 ^d ± 0.57	0.11 ^{a,b} ± 0.02	37.24 ^{a,c} ± 1.16	19.76 ^a ± 1.12
25%Br	0.24 ^{a,b} ± 0.04	4.40 ^{c,d} ± 0.69	0.12 ^{a,b} ± 0.02	26.55 ^b ± 1.77	17.24 ^{a,c} ± 0.92
30%Br	0.25 ^a ± 0.04	3.26 ^a ± 0.57	0.13 ^a ± 0.02	22.37 ^d ± 1.16	19.64 ^a ± 1.12

*The samples have been compressed to 50 % strain

^{a-c} Means in the same column followed by different superscript letters differ significantly ($p < 0.05$)

Table 4 Sensory characteristics of samples investigated in the Step 2

	Color	Appearance	Crust firmness	Crumb firmness	Large bubbles	Overall quality
CTRL-W	7.10 ^b ± 0.02	7.00 ^a ± 0.00	6.30 ^c ± 0.27	7.30 ^a ± 0.27	7.20 ^a ± 0.27	7.30 ^a ± 0.27
CTRL-C	7.50 ^c ± 0.00	7.50 ^a ± 0.00	7.50 ^f ± 0.00	7.50 ^a ± 0.41	7.50 ^a ± 0.00	7.50 ^a ± 0.41
30%Br	7.00 ^a ± 0.00	4.75 ^c ± 0.29	6.00 ^b ± 0.00	4.75 ^{c,d} ± 0.29	4.25 ^{c,d} ± 0.29	4.25 ^{c,d} ± 0.29
2%AG	7.00 ^a ± 0.00	3.67 ^b ± 0.29	5.17 ^d ± 0.29	3.67 ^b ± 0.29	3.50 ^b ± 0.00	3.67 ^b ± 0.29
2%GG	7.00 ^a ± 0.00	4.00 ^b ± 0.71	6.00 ^b ± 0.00	3.75 ^b ± 0.29	3.88 ^{b,c} ± 0.25	3.88 ^{b,c} ± 0.25
2%GU	7.10 ^b ± 0.03	7.50 ^a ± 0.00	7.00 ^a ± 0.00	7.25 ^a ± 0.29	7.38 ^a ± 0.25	7.38 ^a ± 0.25
2%HPC	7.00 ^a ± 0.00	5.17 ^c ± 0.29	4.83 ^c ± 0.29	4.33 ^c ± 0.29	4.50 ^d ± 0.50	4.33 ^d ± 0.29
2%STC	7.10 ^b ± 0.02	6.33 ^d ± 0.29	7.00 ^a ± 0.00	6.50 ^e ± 0.00	6.67 ^f ± 0.29	6.67 ^f ± 0.29
2%TAP	7.00 ^a ± 0.00	5.83 ^d ± 0.29	7.00 ^a ± 0.00	5.17 ^d ± 0.29	5.00 ^e ± 0.00	5.50 ^e ± 0.00

Each descriptor was evaluated on a 0 to 9 scale

^{a-f} Means in the same column followed by different superscript letters differ significantly ($p < 0.05$)

among the agents, only the GU and the STC agents were able to improve the sensory characteristics of bread enriched with bran. In particular, the GU sample allowed realizing a bread very similar to the control samples with an overall quality more than 7. This is in agreement with previous work (Mastromatteo et al. 2012a), where the guar seed flour (2 %) improved the quality of bread enriched with 25 % of yellow pepper flour. These results are also supported by Ribotta et al. (2001, 2004), who showed that the addition of guar gum produced an increase of bread volume and a more open crumb structure. From the mechanical point of view, results listed in Table 5 also confirm the beneficial effects of GU and STC on both dough and final crumb. In fact, very comparable values of tenacity were recorded between samples with these two structuring agents and the CTRL-C bread, thus assessing the ability of these two compounds to promote the creation of a stable network, tenacious and properly deformable (Smitha et al. 2008). The compression test also highlighted that GU and STC assured a more acceptable crumb texture, with low values of $F_{50\%}$ (Table 5) compared to the other hydrocolloids

that provoked a relevant crumb firmness. The different behavior can be explained by the specific interactions between each structuring agent and the other food components. Several studies have been carried out on the effects of hydrocolloids on dough rheology and bread quality, suggesting that the result depends on their origin, chemical structure and concentration (Correa et al. 2013; Ribotta et al. 2005; Lazaridou et al. 2007; Bárcenas et al. 2009).

As stated before, to further optimize the bread performance, other concentrations of the two hydrocolloids GU and STC were used in the bread formulation. Observing all the parameters recorded by the tension test of dough samples (Table 6), it can be noted that very comparable results were recorded at 1 and 3 % with both GU and STC. Moreover, these values were always statistically lower than those recorded with 2 % of structuring agent and for this reason the variation of GU and STC above and below 2 % was not considered relevant to further improve bread quality characteristics. Similar considerations are also valid for results from the compression test of crumb (last column of Table 6). From the sensory evaluation

Table 5 Textural properties of dough and crumb samples investigated in the Step 2

	Tension test				Compression test
	F_{max} (N)	Tenacity (Nmm)	F_{break} (N)	$Strain_{break}$ (%)	* $F_{50\%}$ (N)
CTRL-W	0.18 ^c ± 0.02	3.24 ^{a,b} ± 0.50	0.09 ^c ± 0.01	27.86 ^d ± 1.59	8.91 ^d ± 0.84
CTRL-C	0.25 ^a ± 0.03	3.54 ^{a,b,c} ± 0.19	0.12 ^a ± 0.01	40.25 ^e ± 1.98	6.11 ^c ± 0.87
30%Br	0.25 ^a ± 0.04	3.26 ^{a,b} ± 0.57	0.13 ^a ± 0.02	22.37 ^a ± 1.16	19.64 ^b ± 1.12
2%AA	0.23 ^a ± 0.03	2.97 ^a ± 0.31	0.11 ^{a,c} ± 0.01	17.92 ^b ± 1.10	30.93 ^a ± 1.07
2%GG	0.24 ^a ± 0.02	3.09 ^{a,b} ± 0.34	0.12 ^a ± 0.01	18.55 ^{b,c} ± 0.92	34.51 ^f ± 1.16
2%GU	0.25 ^a ± 0.02	3.72 ^{a,b,c} ± 0.21	0.12 ^a ± 0.02	20.96 ^a ± 1.02	15.89 ^e ± 0.98
2%HPC	0.34 ^b ± 0.04	5.12 ^d ± 0.58	0.17 ^b ± 0.02	20.53 ^{a,c} ± 0.97	29.06 ^a ± 1.07
2%STC	0.31 ^b ± 0.03	3.87 ^{b,c} ± 0.74	0.15 ^b ± 0.01	20.12 ^{a,b,c} ± 0.97	19.64 ^b ± 1.33
2%TAP	0.30 ^b ± 0.03	4.11 ^c ± 0.28	0.15 ^b ± 0.01	21.85 ^a ± 1.05	31.91 ^a ± 1.08

* The samples have been compressed to 50 % strain

^{a-f} Means in the same column followed by different superscript letters differ significantly ($p < 0.05$)

Table 6 Textural properties of dough and crumb samples: screening of the level of structuring agents chosen in Step 2

	Tension test				Compression test
	F_{max} (N)	Tenacity (Nmm)	F_{break} (N)	$Strain_{break}$ (%)	* $F_{50\%}$ (N)
CTRL-W	0.18 ^{a,b} ± 0.02	3.24 ^a ± 0.50	0.09 ^a ± 0.01	27.86 ^d ± 1.59	8.91 ^b ± 0.84
CTRL-C	0.25 ^c ± 0.03	3.54 ^a ± 0.19	0.12 ^b ± 0.01	40.25 ^c ± 1.98	6.11 ^d ± 0.87
30%Br	0.25 ^c ± 0.04	3.26 ^a ± 0.57	0.13 ^b ± 0.02	22.37 ^c ± 1.16	19.64 ^c ± 1.12
1%GU	0.17 ^{a,b} ± 0.02	1.77 ^b ± 0.19	0.09 ^a ± 0.01	15.27 ^a ± 0.94	15.68 ^a ± 0.97
2%GU	0.25 ^c ± 0.02	3.72 ^a ± 0.21	0.12 ^b ± 0.02	20.96 ^{b,c} ± 1.02	15.89 ^a ± 0.98
3%GU	0.15 ^a ± 0.01	1.74 ^b ± 0.08	0.08 ^a ± 0.01	16.16 ^a ± 1.05	10.65 ^b ± 0.55
1%STC	0.20 ^b ± 0.01	2.37 ^b ± 0.13	0.10 ^a ± 0.01	17.31 ^a ± 0.93	15.58 ^a ± 0.94
2%STC	0.31 ^d ± 0.03	3.87 ^a ± 0.74	0.15 ^c ± 0.01	20.12 ^b ± 0.97	19.64 ^c ± 1.33
3%STC	0.18 ^{a,b} ± 0.01	2.00 ^b ± 0.20	0.09 ^a ± 0.01	15.18 ^a ± 0.99	16.68 ^a ± 1.35

* The samples have been compressed to 50 % strain

^{a-c} Means in the same column followed by different superscript letters differ significantly ($p < 0.05$)

of samples with different amounts of GU and STC (data not shown) acceptable scores were recorded, above 6, thus demonstrating that hydrocolloids, regardless of the concentration, are necessary to adjust this bran-enriched bread acceptance but no improvement in sensory quality was recorded with other concentrations than 2 %. The Table 7 reports the nutritional properties of the optimized bread samples with the two structuring agents, compared to the control breads and to sample without any agent (30%Br). Data highlight that between the two structuring agents the only relevant difference is the content of soluble fibers, higher in sample with GU than in that with STC, most probably due to the fact that guar seed flour is classified as a soluble fiber (Aravind et al. 2012). Comparing all the samples it is worth noting that the last breads optimized from the sensory point of view, also recorded a good nutritional composition, very comparable to the bran-enriched 30%Br sample. Fat and ash are similar whereas, a slight decrease of proteins, fibers and selenium contents between the 30%Br bread and the two optimized samples was found, probably due to a dilution effect. In addition, these differences could be explained in terms of chemical structure of agents and their interactions with the different molecules (Bárceñas et al. 2009). A part from these slight differences between samples, the work carried out demonstrates that the functional bread with hydrocolloids not only became

acceptable but also nutritionally better than both the conventional and the whole-meal samples, due to the high amount of added bran. It is worth noting that if compared to standard durum wheat bread very high concentrations of proteins, fibers and selenium can be found. In a previous work of Mastromatteo et al. (2013) numerous durum wheat varieties were utilized to produce bread and generally, total fibers ranged between 5 and 7 %.

Correlations

The correlations between the textural, sensory and nutritional parameters of the investigated bread samples were also evaluated (Table 8). From the Table 8 it can be seen that there is a significant correlation between all parameters except for the tenacity of dough. Brady and Mayer (1985) also obtained low correlation coefficients between sensory and instrumental analysis of textural attributes of rye and French bread. Regarding the other parameters, Table 8 shows a strong correlation between $F_{50\%}$ (crumb strength, i.e. peak resistance to deformation) and overall quality. In fact, the force required for a breadcrumb deformation is inversely correlated to the overall quality: the higher the crumb strength (hardness crumb), the lower the overall quality of bread. This evidence can be described by means of attributes as softness/hardness that

Table 7 Nutritional properties of samples: screening of structuring agents levels chosen in Step 2

	Fat (%)	Protein (%)	Ash (%)	TDF (%w/w)	IDF (%w/w)	SDF (%w/w)	Selenium (ppm)
CTRL-W	4.71 ^c ± 0.01	15.88 ^c ± 0.07	4.40 ^c ± 0.02	15.69 ^b ± 0.53	12.01 ^c ± 0.96	3.95 ^c ± 0.43	4.92 ^b ± 0.04
CTRL-C	4.26 ^b ± 0.20	14.99 ^b ± 0.01	3.74 ^a ± 0.18	10.05 ^a ± 1.22	7.22 ^b ± 1.13	2.83 ^a ± 0.09	3.98 ^a ± 0.18
30%Br	5.28 ^a ± 0.01	16.06 ^d ± 0.03	4.75 ^d ± 0.03	22.42 ^c ± 0.21	17.85 ^d ± 0.07	4.57 ^b ± 0.28	5.79 ^c ± 0.03
2%GU	5.30 ^a ± 0.14	11.72 ^a ± 0.01	4.13 ^b ± 0.04	19.48 ^d ± 0.40	14.93 ^a ± 0.01	4.79 ^b ± 0.05	3.97 ^a ± 0.03
2%STC	5.30 ^a ± 0.42	11.74 ^a ± 0.06	4.10 ^b ± 0.14	18.05 ^c ± 0.06	15.06 ^a ± 0.08	2.94 ^a ± 0.05	3.90 ^a ± 0.02

^{a-c} Means in the same column followed by different superscript letters differ significantly ($p < 0.05$)

Table 8 Correlation among textural, sensorial and nutritional parameters of bread samples

	Tenacity (Nmm)	F _{50%} (N)	Overall quality	Protein (%)	TDF (%w/w)
Tenacity (Nmm)	1	0.091347	−0.053895	−0.383193	−0.33015
F _{50%} (N)	−	1	−0.961459 ^a	0.599786 ^a	0.823184 ^a
Overall quality	−	−	1	−0.630277 ^a	−0.852895 ^a
Protein (%)	−	−	−	1	0.918461 ^a
TDF (%w/w)	−	−	−	−	1

^a Highly and significantly correlated

strongly contribute to consumer freshness perception (Jensen et al. 2010). In addition, it is worth considering that overall quality of bread is markedly affected by its formulation. In this regard, Table 8 shows that also proteins and TDF contents were strongly correlated with the sensory quality: the increase of fibers and proteins decreased the overall quality because of the less soft crumb (high F_{50%}). Dhinda et al. (2012) also observed that crumb firmness increased with the increase of the soy protein isolate, oat bran and chickpea flour added to the formulation. Most probably, the high amount of fibers and proteins might have disrupted the well-defined protein–starch complex of dough. It is worth noting that, in the bread making process it is necessary to obtain a balanced network force: if the gluten structure is too strong it would not allow the bubbles formed by the yeast to grow, whereas the weakened gluten structure is unable to cope with the increase in gas associated with the leavening process and this causes the collapse of the structure (Lookhart 1997). In fact, proper gluten network strength able to hold the gas formed by the yeast and to counterbalance its pressure is highly desirable to obtain good products.

Conclusions

A study on the textural, nutritional and sensory quality of bread manufactured with durum wheat semolina (cultivar PR22D89) enriched with different levels of bran (5, 10, 15, 20, 25, and 30 %) was carried out. Both conventional and whole-meal bread from the same cultivar were also taken into account. The formulation of the functional bread enriched with 30 % bran was optimized by means of proper structuring agents because results showed that the increase of bran to 30 % caused a decrease of bread quality. To improve the poor aptitude of baking of the sample, the screening of different hydrocolloids showed the best results with guar seed flour and modified food-starch-CAPSUL® added at concentration of 2 %. Since the cultivar PR22D89 has a good aptitude to be processed, could represent a valid raw material for functional bread production. In fact, compared to a standard hard wheat bread this product was very rich in proteins, fibers

and selenium. The findings of the current work demonstrated that with proper technological options, a further fortification with bran addition could be realized without compromising its acceptability.

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