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ORIGINAL PAPER

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Effect of dietary fibre on dough rheology and bread quality

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Abstract Dietary fibre is a common and important ingredient of a new generation of healthy food products demanded more each day by customers. Dietary fibre increases the nutritional value of bread but usually at the same time alters rheological properties of dough and, finally, the quality and sensorial properties of bread. The present work investigates the effect of some purified dietary fibres from different origins (orange, pea, cocoa, coffee, wheat and microcrystalline cellulose) on the rheological properties of wheat flour dough and the final quality of breads. The study of the rheological behaviour of the dough was performed by means of a consistograph and an alveograph. Bread quality was determined by means of texture, colour and specific volume measurements after baking under controlled conditions. The influence of fibre on bread sensory evaluation was established. Dietary fibre additions, in general, had pronounced effects on dough properties yielding higher water absorption, mixing tolerance and tenacity, and smaller extensibility in comparison with those obtained without fibre addition (in the control bread). Regarding the effect on bread properties, the fibre always enhanced the shelf life, as textural studies revealed. Sensory evaluations revealed that dietary fibres, with the exception of those from coffee and cocoa, can be added to flour at the level of 2% without deterioration of the bread palatability in comparison with white flour bread. Additions of 5% could imply the use of some additives to correct the rheological properties of dough.

Keywords Dietary fibre · Rheology · Baking · Wheat flour dough · Bread quality.

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Introduction

Nowadays, there is a growing demand for a new generation of healthier food products which at the same time have excellent sensory qualities [1]. The diet of developed countries is at present deficient in fibre, which leads to numerous health complications [2]. Today there are two reasons to add fibre to baked products: the increase of dietary fibre intake and the decrease of the caloric density of baked goods [3].

Dietary fibre is the remnant of the edible part of plants and analogous carbohydrates that are resistant to digestion and absorption in the human small intestine, with complete or partial fermentation in the human large intestine. It includes polysaccharides, oligosaccharides, lignin and associated plant substances. Dietary fibre exhibits one or more of either laxation (faecal bulking and softening, increased frequency and/or regularity), blood cholesterol attenuation, and/or blood glucose attenuation [4]. The functional properties of fibres depend on the fibre source and the type and degree of processing [5,6].

A great number of dietary fibre sources are available to bakeries today, some of them with a relatively high level of soluble dietary fibre (SDF). The presence of a SDF fraction in dietary fibre can provide improved physiological functions in addition to the functional effects provided by the insoluble dietary fibre (IDF) fraction [6,1]. Many authors have studied the use of high percentages of different kind of dietary fibre in baking but they have usually found important detriments to dough handling and bread quality, unless some food additives were used. The main problem of dietary fibre addition in baking is the important reduction of loaf volume and the different texture of the breads obtained. Chen et al. used apple fibre in bread making and observed that the addition of 4% hydrated apple fibre reduced loaf volume by 14% [7]. Pomeranz et al. used cellulose, wheat brans and oats hulls as fibre sources in bread-making and observed that the final volume of breads was lower and with different texture than fibre-free bread [8]. Krishnan et al. tested commercial oat brans and observed that inclusion decreased the bread loaf volume [9]. Likewise, Sievert et al. tested a soy polysaccharide blend (10%) in Chinese steamed bread and observed a detrimental effect on volume and texture [10]. Soluble and insoluble dietary fibres have also been added to cakes and other cereal products different to bread [11, 12,13].

Frequently, some additives such as vital gluten and surfactants [14], sodium stearoyl-2-lactylate (SSL) [9, 15] or bromate and SSL [16] are used to counteract the deleterious effect of fibre addition on the dough handling characteristics, loaf volume reduction and acceptability of the bread. These additives improve the overall quality of fibre-supplemented bread but, in general, there still remain pronounced differences to white bread.

Keeping in mind the necessity of increasing dietary fibre ingestion (especially in Western societies) and taking into account that customers demand healthier foods but at the same time with high sensory quality, this research work was mainly focused on the possibility of offering breads with an improved nutritional value and simultaneously with high consumer acceptance, but without food additives. This work includes a systematic study on the effect of fibres of different origin on the rheological properties of dough. Low quantities (2%–5%) of dietary fibres from different origins (pea, cocoa, coffee, orange, wheat and microcrystalline cellulose) were added to wheat flour and the effects on the handling characteristics of dough and the quality of bread were studied.

Materials and methods

Materials

Commercial blends of Spanish wheat flour (12.84% protein) were obtained from the local market. Fibres from different origins were generously gifted by Campi y Jové (Barcelona, Spain). The fibres tested, together with the distributor's reference number, were: orange fibre (OF 400/30), pea fibre (ID 90), cocoa fibre (ID 67), coffee fibre (ID 68), microcrystalline cellulose (L 102) and wheat fibre (WF 200 and WF 600/30). Two different wheat fibres were tested in order to study the influence of fibre size. The WF 200 fibre has an average fibre length of 250 μm (in this work it will be called wheat-L) while the WF 600–30 has an average fibre length of 35 μm (wheat-S). Table 1 summarises the composition of dietary fibres provided by manufacturer.

Table 1 Standard dietary fibre composition (%, dry basis)

Origin	TDF	IDF	SDF	Starch	Protein
Microcrystalline cellulose	99	99	0	0	0
Pea	88	78.3	9.7	3	6
Cocoa	67	43.6	23.4	8	20
Coffee	68	44.2	23.8	0	20
Orange	66	36	30	23	7
Wheat-L	97	94.5	2.5	0	0.4
Wheat-S	97	94.5	2.5	0	0.4

TDF total dietary fibre determined by the AOAC method, *IDF* insoluble dietary fibre, *SDF* soluble dietary fibre

Methods

Dough rheological characteristics

Consistograph test was performed using a Consistograph NG (Tripette et Renaud, France) following the supplier specifications [17]. The following consistograph parameters were automatically recorded by a computer software program: water absorption (HA, water required to yield dough consistency equivalent to 1700 mb of pressure in a constant humidity measurement), dough development time (TPr, time to reach maximum consistence in an adapted humidity determination with a maximum pressure of 2200 mb), tolerance (Tol, time elapsed since dough consistency reaches its maximum until it decreases down to 20%), decay at 250 s (D250, consistency difference, in mb, between height at peak and to that 250 s later), decay at 450 s (D450, consistency difference, in mb, between height at peak and its value 450 s later). Decay at 250 s and 450 s are related to dough mixing stability. Higher stability means lower D250 and D450 values.

Alveograph test was performed using an Alveograph MA 82 (Tripette et Renaud, France) following the standard method [18] at adapted hydration. The following alveograph parameters were automatically recorded: tenacity or resistance to extension (P), dough extensibility (L), curve configuration ratio (P/L) and the deformation energy (W).

The average results of two separate determinations are presented in all cases.

Bread-making procedure

A straight dough process was carried out for preparing the bread samples. A basic bread formula, based on flour weight, was used: 2000 g of flour (14% moisture content basis), water up to 1700 mb consistency, 4% compressed yeast and 2% salt. When fibres were added, they replaced 2% or 5% of flour. The dough was mixed for 15 min, divided into 600 g pieces, hand-moulded and sheeted, put into tin pans for 75 min at 29 °C and 70% RH. Bread was baked in an electric oven for 35 min at 215 °C. Bread quality attributes were evaluated after cooling for 2 h at room temperature.

Evaluation of bread quality

Bread quality analysis included: weight, volume (determined by seed displacement in a loaf volume meter), crumb firmness, crumb and crust colour and sensorial analysis.

Crumb firmness was measured using a TA-XT2 texture analyser (Stable Microsystems, Surrey, UK) provided with the software "Texture Expert". In order to establish the evolution of the bread quality during storage, texture measurements were also performed. An aluminium 25 mm diameter cylindrical probe was used in a "holding-until-time" compression test. The probe speed during the test was 2 mm/s and the compression distance 10 mm. The resulting peak force was measured in grams. In bread texture determinations, ten different slices of 25 mm thickness were measured. The averaged result is presented.

Colour was measured using a Minolta spectrophotometer CN-508i (Minolta, Japan). The tristimulus values were automatically calculated from the spectrum by means of a computer program. Results were expressed in the CIE L*a*b* colour space and were obtained using the D65 standard illuminant and the 2° standard observer (CIE 1931). All colour determinations were made 10×5 times: crumb or crust colour was checked at ten different points on each piece of bread and every point was measured five times. Averaged results are presented.

Sensory evaluation

Sensory evaluations of bread were conducted by 40 panellists, consisting of Agricultural Engineering College staff and students

Table 2 Consistograph analysis of fibre-supplemented dough and free-fibre dough (the control)

	Fibre addition (%)	HA (%)	TPr (min)	Tol (min)	D250 (mb)	D450 (mb)
Control	0	58.7	126	176	481	995
Microcrystalline cellulose	2	60.4	140	235	261	787
Pea	2	59.9	166	237	195	793
Cocoa	2	60.6	156	214	265	871
Coffee	2	59.6	144	212	330	871
Orange	2	63.0	150	186	376	1016
Wheat-L	2	60.2	138	224	320	781
Wheat-S	2	60.3	148	260	215	702
Orange	5	65.4	188	202	152	873
Wheat-L	5	63.8	190	364	26	431
Wheat-S	5	61.4	161	264	239	670

HA water absorption, *TPr* dough development time, *Tol* tolerance, *D250* decay at 250 s, *D450* decay at 450 s

using a one to nine hedonic rating scale for the overall acceptability, where nine means extreme satisfaction and one extreme dissatisfaction.

Statistical analysis

Data obtained were analysed using standard statistical packages for Windows. Significance of differences between control and treated samples was evaluated using Duncan's multiple range test at 5% level.

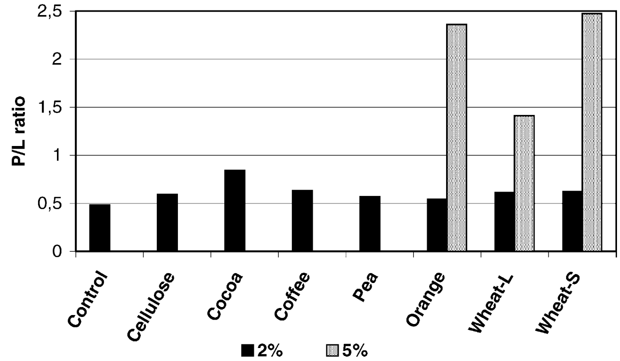

Fig. 1 Effect of the addition of different dietary fibres on the P/L ratio of the configuration curve measured by the alveograph

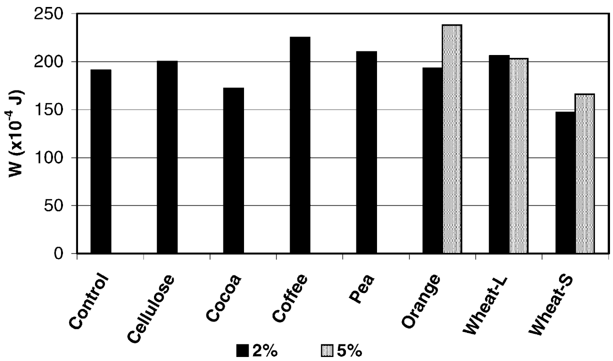

Fig. 2 Effect of several dietary fibres on the deformation energy of wheat flour dough measured by the alveograph

Results and discussion

Effect of different fibres on consistograph parameters

Table 2 summarises consistograph results of dietary fibre-supplemented dough and the control dough (without fibre addition). It shows that water absorption was increased by fibre addition. This result agrees with that found by other authors with different kinds of fibre and hydrocolloids, although they were usually obtained with a farinograph or mixograph apparatus [19, 20]. This result was expected due to the hydroxyl groups in the fibre structure, which allow more water interactions through hydrogen bonding. The highest water absorption was observed with the orange fibre. No significant differences in water absorption were detected between the rest of fibres tested at 2% level, all of which showed lower absorption than the former. The increase from 2% to 5% in fibre addition led to a notable increase in this parameter.

Time required for dough development, or to reach a dough consistency equivalent to 2200 mb pressure (TPr), was always increased as a consequence of fibre additions, although to a different extent depending on fibre's origin and its particular composition. Wheat fibre and microcrystalline cellulose, with higher insoluble fibre content, led to the lowest increase in TPr parameter, while the orange, cocoa and coffee fibres, with a high SDF fraction, yielded the highest dough development time.

Fibre additions always increased dough tolerance (higher Tol values) and stability (lower D250 and D450 values), independently of the fibre source. At the 2% level, wheat-S fibre exhibited the maximum effect on dough tolerance – notably higher than the dough supplemented with wheat-L fibre – while orange fibre led to the minimum effect. However, for a 5% fibre level, the highest dough tolerance and stability were obtained with wheat-L fibre.

Regarding the consistograph results, it can be concluded that fibre-supplemented dough allowed higher water addition during the mixing process, implying longer mixing times, and was more tolerant to an excess of mixing than the fibre-free dough. These effects were, in general, more relevant when fibre additions were increased from 2% to 5%.

Effect of different fibres on alveograph parameters

The effects of fibre addition on the alveograph parameters of wheat flour dough are shown in Figs. 1 and 2. Dough resistance to deformation or tenacity (P) gives information about the handling characteristics of the dough. Likewise, the extensibility of dough (L) is an indicator of the handling characteristics of the dough, particularly the capacity of extending it without breaking down. The addition of fibre always increased the dough tenacity (P) and reduced the dough extensibility (L). Consequently, the P/L ratios (which give information about the elastic resistance balance of flour dough and summarise the effect of P and L parameters) always showed an increase. This increase was moderate in 2% fibre-supplemented dough, without showing any significant differences between fibres from different origin except when cocoa fibre was added, which showed a notably higher effect (Fig. 1). When 5% of dietary fibre was added (orange and wheat fibre) the P/L ratio reached very high values (2.47 for wheat-S fibre and 2.36 for orange fibre vs. 0.48 in the control dough). In this case, the use of additives to improve the handling characteristics of dough would be necessary. This effect could be due to the interactions between dietary fibre and the wheat flour proteins [21].

The effect of dietary fibre addition on the deformation energy (W) followed different trends (Fig. 2). In general, all the fibres tested led to a moderate increase (up to 18%) in the deformation energy (W), with the exceptions of the wheat-S fibre and the cocoa fibre that decreased the dough strength by 23% and 10%, respectively. When the addition was increased until 5%, no clear difference was observed with 2% additions.

It is worthnoting the differences found in rheological behaviour of the dough when wheat fibres of different length were added.

Effect of fibre addition on final bread characteristics

Colour

The effect of fibre addition on the bread colour is summarised in Figs. 3 and 4. The colour difference, ΔE^*_{ab} (taking the control bread colour as reference) shows the influence of fibre additions on the bread colour. Although the original colour of ingredients can have some influence on the crust bread colour this is mainly associated to Maillard and caramelization reactions. However, the crumb bread colour is usually similar to the colour of the ingredients because the crumb does not reach as high temperatures as the crust. In general, no significant differences were observed between the crust of the control bread and the crust of 2% fibre-supplemented bread, as can be seen in Fig. 3. An important difference in crust colour was observed only when cocoa and coffee fibres were used. This difference was related to the low lightness, L*, in comparison with the control, as consequence of its darker colour. However, breads with 5% of wheat-S fibre were lighter than the control.

Cocoa and coffee fibres produced dark crumb and led to the highest colour differences (see Fig. 4). This fact was due to the influence of the original colour of these fibres. In general, white or clear fibres yielded breads with a crumb and crust colour very similar to the control bread. The orange fibre showed a very slight orange colour not detected on crumb bread at 2% level. However, at 5%, the orange fibre-supplemented bread showed a notably darker crumb colour than the control one.

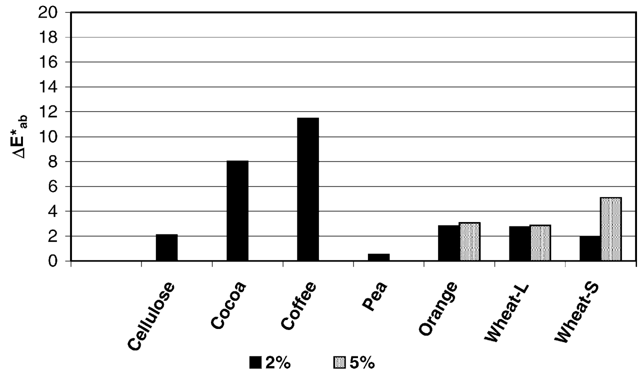

Fig. 3 Colour difference in the crust of bread supplemented with fibre, taking as reference the free-fibre bread colour. $\Delta E_{ab}^* = ((\Delta a^*)^2 + (\Delta b^*)^2 + (\Delta L^*)^2)^{1/2}$. Values are the average of 10×5 measurements

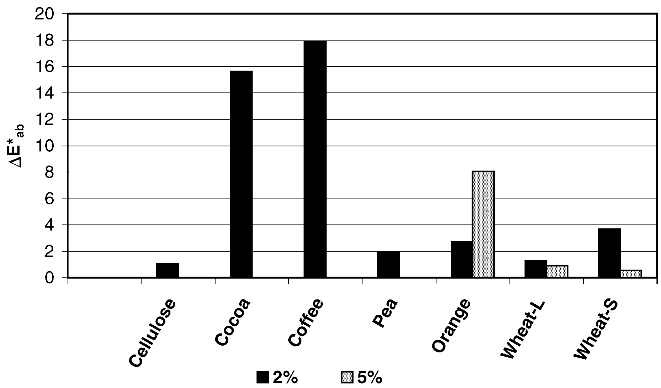

Fig. 4 Colour difference in the crumb of bread supplemented with fibre, taking as reference the free-fibre bread colour. $\Delta E_{ab}^* = ((\Delta a^*)^2 + (\Delta b^*)^2 + (\Delta L^*)^2)^{1/2}$. Values are the average of 10×5 measurements

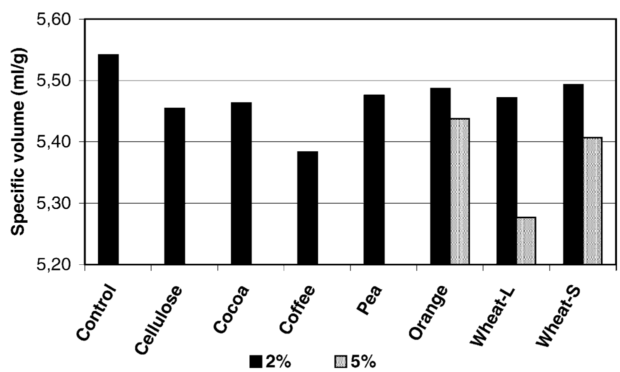

Fig. 5 Specific volume of fresh bread containing fibre from different origins and free-fibre bread (control). Values are the average of five different measures

Specific volume

The effect of fibre addition on the specific volume of bread is shown in Fig. 5. The specific volume always de-

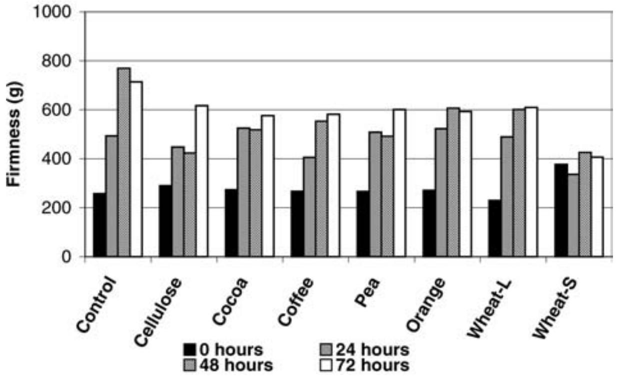

Fig. 6 Effect of 2% fibre addition on the crumb firmness of fresh bread (0 h storage) and its evolution after 24–72 h storage

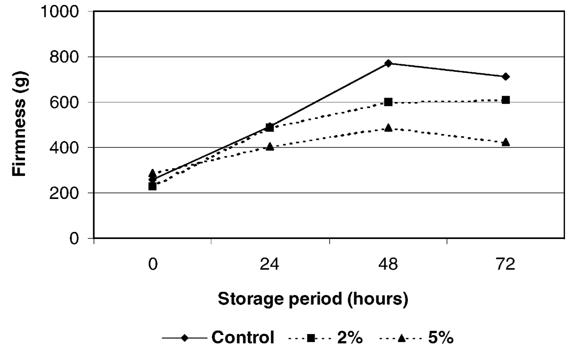

Fig. 7 Effect of 2% and 5% of wheat-L fibre (average fibre length of 250 μm) addition on the evolution of crumb firmness during a storage period of 72 h

creased as consequence of fibre addition, which has already been reported [8]. This effect is attributed to the interaction between fibre and gluten, which led to a decrease in the gas retention capacity. As expected, the effect was more evident when the fibre addition was increased from 2% to 5%. In 2% fibre-supplemented bread the lowest volume was obtained when coffee fibre was used. The rest of the fibres tested led to bread with very similar specific volumes to the control bread. The smallest piece of bread was obtained when 5% of wheat-L fibre was added.

Firmness

In general, 2% fibre-supplemented fresh bread had significantly firmer crumb texture than control bread. Pieces with 2% wheat-S fibre produced the greatest increase in firmness, nearly 50%. This effect, also found by other authors [22], is probably due to the thickening of the walls surrounding the air bubbles in the crumb. Only breads with 2% of wheat-L fibre showed a slightly decreased hardness (see Fig. 6). Again, a notable difference was observed between the effect of the two kinds of wheat fibre.

The crumb firmness evolution during a storage period of 3 days showed the important effect of fibre addition on bread lifetime. This effect is related to the well-known water binding capacity of fibre that avoids water loss during storage and with the possible interaction between fibre and starch that would delay the starch retrogradation. As can be seen in Fig. 6, the most notable difference in hardening between the fibre-supplemented bread and the control was observed after 2 days of storage. It can also be seen that wheat-S fibre showed the best effect in delaying the bread hardening. The effect was always more notable when the fibre addition was increased from 2% to 5%, as can be seen in Fig. 7 where the effect of addition of wheat-L fibre is presented.

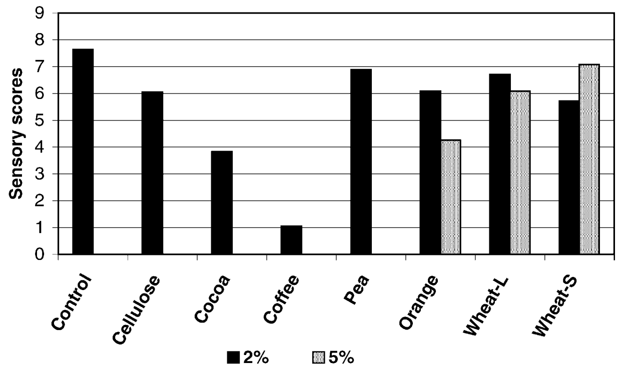

Fig. 8 Sensory scores for overall acceptability of bread supplemented with dietary fibre

Sensory evaluation

Figure 8 shows averaged sensory scores for the overall acceptability of the fibre-supplemented bread. Significant differences in acceptability were obtained between fibres of different origins. In general, panellists preferred bread without fibre added. Nevertheless, all the breads were acceptable except when coffee and cocoa fibres were added. Scores were markedly lower in these cases, probably due to the notable differences in colour, flavour and odour of these breads as result of the original properties of the fibres. There was no clear relationship between the sensory score and the quantity of fibre added. This also depended on the kind of fibre tested. As can be seen in Fig. 8, panellists preferred bread with a higher addition of wheat-S fibre. On the contrary, bread supplemented with 5% orange fibre obtained a notably lower score than that with 2% addition.

Conclusion

The handling characteristics of wheat flour dough were modified to different extents by fibres of different origins and length, although in general the rheological properties were altered in the same direction by all the fibres tested. Dietary fibre, in general, had pronounced effects on dough properties yielding higher water absorption, mixing tolerance and tenacity, and smaller extensibility in comparison to the control bread without fibre addition.

Small additions of dietary fibre to wheat flour (at the 2% level) produced, in general, very similar bread to the white wheat bread without any noticeable damage to acceptability. Furthermore, these breads, with an added nutritional value, showed a longer lifetime since the hardening tendency was markedly reduced in comparison with the control bread. It could also be concluded that the kind of dietary fibre added had an influence on bread quality since significant differences were found when fibres of different origin and length were tested. Cocoa and coffee fibres yielded the worst bread sensory quality. The rest of the fibres tested yielded bread of good enough acceptability.

The increase of wheat fibre addition to 5%, with the inherent enhanced positive nutritional effect, did not deteriorate the bread sensory evaluation. Nevertheless, some additives, such as vital gluten or oxidising and emulsifying agents, would have to be added to counteract the unwanted effect of fibre addition on the dough handling characteristics and the bread volume reduction.

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