ELSEVIER

Food Chemistry 79 (2002) 221–226

Food Chemistry

www.elsevier.com/locate/foodchem

Effect of the addition of different fibres on wheat dough performance and bread quality

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Received 22 May 2001; received in revised form 21 January 2002; accepted 21 January 2002

Abstract

A good correlation has become evident between fibre consumption and the reduction of coronary heart-related diseases and diabetes incidence. However, fibre intake is commonly lower than recommended. In consequence, the development of foods with high fibre content should be desirable. The potential use of various commercial fibres (carob fibre, inulin and pea fibre), as fibre-enriching agents in breadmaking, is reported. The effects of the addition of these fibres to wheat flour on the viscoelastic properties of dough and both mixing and proofing behaviour is presented. Bread evaluation revealed that carob and pea fibre supplementation, although decreasing specific loaf volume (very slightly in the case of carob fibre), conferred softness to the bread crumbs. In addition, sensory evaluation showed that consumer panellists judged these fibre-enriched breads as acceptable. Therefore, their use, especially carob, allows an increase of the daily intake of fibre without promoting negative effects on the rheological properties of doughs or quality and overall acceptability of the resulting breads. The whole study indicates that these three fibres can be used as additives in breadmaking in order to fortify the diet.

Keywords: Dietary fibre; Rheology; Dough properties; Breadmaking; Bread quality; Texture profile analysis

1. Introduction

Dietary fibre (DF) is the food fraction that is not enzymatically degraded within the human alimentary digestive tract. The main components are cellulose and lignin, but also the hemicelluloses, pectins, gums and other carbohydrates not digestible by human digestive tract (Stear, 1990). The dietary fibre is composed of total dietary fibre (TDF), which includes both soluble (SDF) and insoluble dietary fibre (IDF). The importance of the dietary fibre is increasing due to its beneficial effects on the reduction of cholesterol levels and the risk of colon cancer (Anderson, 1991; Whitehead, 1986). Health authorities, world-wide, recommend a decrease in the consumption of animal fats and proteins and an increase of cereal intake, which is an important source of dietary fibre, and, in most European countries, cereals constitute the major source of dietary fibre. Nevertheless, white bread is a commonly consumed type of bread. Therefore, to meet this requirement for dietary fibre, the development of enriched bread with a higher dietary fibre content should be the best way to increase the fibre intake.

Bread can be enriched with dietary fibre, including wheat bran (Ranhotra, Gelroth, Astroth, & Posner, 1990; Sidhu, Al-Hooti, & Al-Saqer, 1999), gums, such as guar gum and modified cellulloses (Pomeranz, Shogre, Finney, & Bechtel, 1977), and β-glucans (Knuckles, Hudson, Chiu, & Sayre, 1997). However, the addition of these fibres causes a neglected effect on the final bread quality. The most evident effect is the reduction of loaf volume, the increase of crumb firmness, the dark crumb appearance, and also in some cases a modified bread taste is obtained, for instance, when adding guar gum (Knuckles et al., 1997; Lai, Hoseney, & Davis, 1989; Pomeranz et al., 1977). Moreover, the resultant fibre-rich doughs have high water absorption, become shorter and have a reduced fermentation tolerance (Gan, Galliard, Ellis, Angold, & Vaughan, 1992; Laurikainen, Harkonen, Autio, & Poutanen, 1998; Park, Seib, & Chung, 1997).

Different proposals have been reported to solve these problems. One is the use of different milling fractions,

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0308-8146/02/$ - see front matter
PII: S0308-8146(02)00135-8

since the particle size of the bran seems to play an important role (Glitso & Bach Knudsen, 1999); however, this has been a research approach without a possible scale-up. Another alternative is the addition of exogenous enzymes, such as hemicellulases or pentosanases to degrade the cell walls (Haseborg & Himmelstein, 1988; Laurikainen et al., 1998). Nevertheless, there are currently emerging new fibres from different sources, which are potentially useful for making high-fibre breads, whilst diminishing the inherent problems associated with the use of fibres. Lately, Abdul-Hamid and Siew Luan (2000) have reported the potential use of defatted rice bran as a source of dietary fibre in breadmaking. They showed the effect of defatted rice bran addition on bakery products; this study was focussed on the final quality of breads showing a reduced loaf volume and increase firmness, although no information was presented relating to bread dough.

The aim of the present research was to determine the potential use of various commercial fibres from different sources, through a systematic study of the influence of several fibres on the rheological properties of bread doughs and the final quality of the resulting breads. The sensory evaluation and nutritional value of these enriched breads were also evaluated.

2. Materials and methods

2.1. Materials

A commercial blend of wheat flour (14.6% moisture, 11.3% protein and 0.61% ash) was used. Three different fibres (carob fibre, chicory inulin and pea fibre) were used to make enriched fibre bread. Carob fibre (CF) was donated by Carob General Applications, S.A. (Spain), whereas chicory inulin and pea fibre were gifts from Juliá-Parrera, S.A. (Spain). Commercial compressed yeast was used for the breadmaking.

2.2. Methods

2.2.1. Chemical analysis

Moisture, ash, and protein were determined following standard AACC methods (1983). Nitrogen content was measured by the semimicro-Kjeldahl method. Nitrogen was converted to protein by using a factor of 5.7. Soluble, insoluble and total dietary fibre content was determined according to the AACC Method (1996).

2.2.2. Dough characteristics

The effect of the different fibres on dough rheology during mixing was determined by a Farinograph (Brabender, Duisburg, Germany), following the AACC Method (1983). The parameters determined were: water absorption or percentage of water required to yield dough consistency of 500 BU (Brabender Units), dough development time (DDT, time to reach maximum consistency in minutes), stability (time dough consistency remains at 500 BU), mixing tolerance index (MTI, consistency difference between height at peak and that 5 min later, BU) and elasticity (band width of the curve at the maximum consistency).

The viscoelastic behaviour of the dough was determined by the alveograph test, using an Alveograph MA82 (Tripette et Renaud, France), following the standard method (AACC, 1994). The monitored parameters were the deformation energy (W), tenacity or resistance to extension (P), dough extensibility (L) and curve configuration ratio (P/L ratio) of dough, with or without fibres. The proteolytic degradation was determined by measurement of the alveograph parameters after 3 h of dough pieces incubation (Colas, 1974).

The rheological properties of dough during fermentation were determined using a Rheofermentometer F2 (Tripette et Renaud, France), according to the supplier specifications. Registered parameters: maximum dough fermentation height (H_m), the time at which dough attains the maximum height (T_1), loss in dough height after 3 h (Vol.loss), the time of maximum gas formation (T'_1), dough permeability by time when gas starts to escape from the dough (T_x), and the gas retention (volume of the gas retained in the dough at the end of the assay). More information about this equipment is reported by Erdogdu-Arnoczky, Czuchajowska, and Pomeranz (1996), and Rosell, Rojas, and Benedito (2001).

Alveogram and rheofermentogram studies were carried out at the same dough consistency as control (without fibre), since water adsorption was greatly modified by the addition of fibres.

All determinations were made at least in duplicate, and the average values were adopted.

2.2.3. Baking tests

A straight dough breadmaking process was performed. Basic dough formula on 100 g flour basis consisted of salt (2 g), compressed yeast (2 g), ascorbic acid (50 ppm), the amount of water required to reach 500 BU of consistency, and 3% fibre (when added). Carob fibre, inulin and pea fibre were used as commercial fibres with potential use for enriching breads. The doughs were optimally mixed, fermented for 10 min, then dough pieces (100 g) were divided, hand-moulded and sheeted. Doughs were proofed at 28 °C up to optimum volume increase, and baked at 190 °C for 20 min. The bread quality attributes were evaluated after cooling for 1 h at room temperature.

2.2.4. Bread quality evaluation

Bread quality parameters included weight, volume (determined by seed displacement in a loaf volume meter), specific volume, moisture content, acceptance and texture of crumb. Overall acceptability was carried out as follows: one slice of bread, identified by code numbers, was served to each panellist under normal (daylight) illumination. They evaluated each product for quality attributes: grain, crumb smoothness, aroma, flavour and overall acceptability. Acceptability of each quality attribute was rated with a score 1 (lowest) to 10 (highest). Products were considered acceptable if their mean scores for overall acceptability were above 5 (neither like nor dislike).

Texture profile analysis (TPA) was performed using a TA-XT2i texturometer (Stable Microsystems, Surrey, UK) equipped with a 2.5 cm plug. Crumb slices of 2 cm were 50% compressed. Four replicates from two different sets of baking were analysed and averaged. The parameters recorded were hardness, chewiness, cohesiveness, springiness and resilience.

3. Results and discussions

3.1. Influence of fibres on dough properties

Before determining the effect of the different fibres on dough rheology, their composition was assessed (Table 1). The contents of TDF, SDF and IDF in the three fibres used in the research are listed in Table 1. The main difference among them was the composition of the insoluble dietary fibre. The carob fibre IDF is composed mainly of lignin and polyphenol; the inulin is a mixture of oligo- and polysaccharides of fructose and the pea fibre IDF contains a majority proportion of cellulose.

Table 1
Composition of the commercial fibres used in this study

Components (%)[a]	Carob fibre	Inulin	Pea fibre
Dry matter[b]	97.0	96.3	94.4
Protein	6.4	7.1	5.5
Ash	2.2	1.7	1.4
Fat	<0.5	<0.5	<0.5
Carbohydrates[c]			
Total dietary fibre	85.0	88.6	86.7
Insoluble dietary fibre	74.0	41.4	79.8
Soluble dietary fibre	11.0	47.2	6.9

[a] Dry basis.
[b] As-is basis.
[c] Calculated by difference.

3.1.1. Influence of fibres on mixing properties

The addition of fibres promoted differences on the dough mixing behaviour measured by the farinograph. Table 2 shows the main parameters registered in the farinogram. Fibre addition mainly modified the water absorption. Apart from inulin, a great increase was produced by the addition of fibres and the extent of the increase depended upon the structure of the fibres added. The highest absorption was found with the addition of pea fibre, followed by carob fibre. Similar effects on water absorption were observed when adding wheat bran (Pomeranz et al., 1977), rye bran (Laurikainen et al., 1998), and rice bran (Barber, Benedito de Barber, & Martinez, 1981). This is likely caused by the great number of hydroxyl groups existing in the fibre structure, which allow more water interactions through hydrogen bonding, as was previously found by Rosell et al. (2001), working with different hydrocolloids. Dough development time (DDT) and stability value are indicators of the flour strength, with higher values suggesting stronger doughs. These fibres did not modify the DDT or the stability (with the exception of inulin which increased it), in opposition to the results reported by Laurikainen et al. (1998), who found an increase of the DDT and a decrease of the stability when adding 5% rye bran. Greater effects were observed on the MTI and elasticity; both parameters were reduced by the addition of the tested fibres, and the extent of the decrease depended on the fibre considered. These results could be explained by the interactions between fibres and gluten, as suggested Chen, Rubenthaler, and Schanus (1988). The farinogram result shows that the addition of inulin confers different mixing properties to the dough, surely due to its composition in polysaccharides of fructose.

3.1.2. Influence of fibres on the viscoelastic characteristics of wheat dough

The effects of added fibres on the alveograph characteristics of wheat flour doughs are seen in Table 3. The *P* value (dough resistance to deformation or tenacity) is an indicator of the dough's ability to retain gas. *P* values increased with the addition of the three different fibres. The highest effect was exhibited by inulin, followed by CF, and the lowest influence was by PF. This is likely

Table 2
Farinograph analysis of wheat dough containing different fibres (for abbreviations, see Section 2)

	Water adsorption (%)	DDT (min)	Stability (min)	MTI (BU)	Elasticity (BU)
Control	53.5	2.0	4.0	90	110
Carob fibre	57.3	2.0	4.0	70	100
Inulin	52.0	2.0	5.0	50	90
Pea fibre	59.9	2.0	4.0	75	90

Table 3
Effect of the fibre addition on the alveoghaph characteristics of a wheat flour[a]

	Control[b]	Carob fibre	Inulin	Pea fibre
P (mm H_2O)	48	57	60	53
L (mm)	107	81	106	62
W ($\times 10^{-4}$ J)	119	128	161	102
P/*L* ratio	0.5	0.7	0.6	0.9
Proteolytic degradation (%)	18.5	2.3	0	9.8

[a] *P*, the resistance to deformation; *L*, dough extensibility; *W*, the energy input necessary for deformation; *P*/*L*, the configuration curve ratio.
[b] Control is referred to dough without fibre.

Table 4
Influence of fibre supplementation on the wheat dough behaviour through fermentation (abbreviations are specified in Section 2)

	Control[a]	Carob Fibre	Inulin	Pea Fibre
Dough development				
H_m (mm)	33.5	31.9	30.2	29.4
T_1 (min)	70	69	60	58
Vol. loss (%)	25.3	21.3	0.0	57.9
Gas behaviour				
T_x (min)	73	67	49	61
T'_1 (min)	87	57	63	51
Gas retention (%)	81.8	81.7	81.3	81.4

[a] Control is referred to dough without fibre.

due to interactions between the fibre structure and the wheat proteins, as previously reported Jones and Erlander (1967), who reported interactions between polysaccharides and proteins from wheat flour.

Additionally, *L* (the extensibility of dough), a predictor of the processing characteristics of the dough, was greatly reduced by adding fibres, with the exception of inulin, which did not modify *L*. The highest effect was promoted by pea fibre, yielding a reduction of about 42% in the extensibility of the wheat flour, and hence a smaller bubble before failure. The resulting effect on *P* and *L* became evident in the *P*/*L* ratio value, which provides information about the elastic resistance and extensibility balance of flour dough.

The addition of pea fibre led to the highest *P*/*L* ratio (0.9 vs 0.5 in the control), probably due to the high content of cellulose present in this fibre, which favours a strong interaction between this fibre and the flour proteins.

The influence on *W* (the deformation energy) depended on the fibre considered. *W* was reduced by pea fibre addition, while it was increased by CF and inulin, reaching, in the latter, the highest value (161 vs 119 in the wheat flour). It is important to note that the addition of fibres promoted a marked decrease of the proteolytic degradation, being practically neutralised by inulin and carob fibre, and therefore the addition of these two fibres led to a great improvement of wheat protein behaviour, allowing long proofing times.

3.1.3. Fermentation behaviour of doughs with fibres

The evolution of dough properties throughout the fermentation can be continuously registered by the rheofermentometer, which gives information about dough development, gas production and gas retention (Bloksma, 1990). The influence of fibre additions on the fermentation characteristics is shown in Table 4. Dough heights, when supplemented with fibres, decreased compared to the wheat dough. These were in agreement with the decline of the extensibility and the resistance increase measured by the alveograph. Probably, the interactions between flour proteins (gluten) and these fibres prevent the free expansion of wheat dough during the proofing stage.

The time to reach the maximum dough development (T_1) was not affected by CF, whereas it was reduced by the addition of inulin and pea fibre; this result indicates that fermentations of doughs containing these fibres need less time to reach the maximum than does the control. In addition, inulin and CF decreased the percentage of volume loss, which means higher dough stability than the control. Therefore inulin and CF improve dough characteristics, allowing longer proofing times.

With respect to gas behaviour, T'_1 (the time of maximum gas formation) and T_x (the time at which gas starts to escape from dough) were decreased by fibre addition, which revealed an increase of the dough permeability to carbon dioxide. Galliard (1986) and Gan, Ellis, Vaughan, and Galliard (1989) found that the addition of particulate components, especially bran and epicarp fibres, to doughs promoted a physical disruption of the gluten protein matrix. They explained this by assuming that fibres act as points of weakness or stress concentrations within the expanding dough cell walls.

However, no change in the relationship between gas production and retention, that is the percentage of gas retention (%), was found. Conversely, Pomeranz et al. (1977) assumed that the loaf volume-depressing effect, caused by the addition of cellulose, bran or oat hulls, could be due to a decreased capacity for gas retention.

3.2. Influence of fibres on bread quality evaluation

The effect of the fibre supplementation on bread quality characteristics is summarized in Table 5. Fibre-rich breads, with CF, inulin or PF, had smaller loaf volumes than the control. The addition of pea fibre promoted the greatest volume reduction (20.7%). In terms of specific bread volume, inulin and PF promoted the greatest decrease. The reductions obtained were comparable to those previously reported with added bran, cellulose, or other polysaccharide (Knuckles et al., 1997; Laurikainen et al., 1998; Pomeranz et al., 1977).

Table 5
Effect of dietary fibre supplementation on the wheat bread evaluation[a]

	Control[b]	Carob fibre	Inulin	Pea fibre
Loaf volume (ml)	906	861	733	719
Specific volume (ml/g)	3.5	3.4	2.9	2.8
Moisture content (%)	33.4	35.3	31.8	35.7
TPA parameters				
Hardness	249.3	205.7	268.4	207.3
Chewiness	192.4	157.8	198.4	158.3
Cohesiveness	0.797	0.799	0.792	0.797
Springiness	0.969	0.973	0.962	0.972
Resilience	0.472	0.447	0.439	0.444
Sensory analysis[c]				
Grain	6.2	6.3	5.2	5.9
Crumb smoothness	6.0	6.2	5.4	6.7
Aroma	6.9	6.1	6.7	7.2
Flavour	7.1	5.7	6.7	6.4
Overall acceptability	6.8	6.1	6.3	6.1

[a] Texture profile analysis (TPA) and sensory analysis is included. For experimental details see Section 2.
[b] Control is referred to dough without added fibre.
[c] Nine point hedonic scale ratings: 9 = like extremely and 1 = dislike extremely.

Rogers and Hoseney (1982) reported that whole wheat flour dough, which contains mostly insoluble fibre, had a normal proof height and a normal spread ratio but gave only a slight oven-spring; they attributed this result to an early fixing of the structure and a high level of water in the dough. In fact, fibre-rich breads have higher moisture contents than the control, as can be observed in Table 5. Bread containing inulin was the exception to this trend, since the moisture content was lower than the control.

The texture profile analysis revealed that inulin addition increased crumb firmness, contrasting with the softer crumbs obtained with the addition of carob and pea fibres. The same trend was observed with the chewiness, and the other parameters from the TPA did not show important changes. The crumb softness effect produced by the CF and PF supplementation is noteworthy, since the addition of fibres usually leads to firm crumbs.

Breads containing fibres were judged by the consumer panellists as acceptable, scoring >5 for each specific sensory characteristic and overall acceptability (Table 5). Moreover, the sensory evaluation of the fibre-enriched breads tested in this study was far superior to those obtained with other fibres cited in the literature (Abdul-Hamid & Siew Luan, 2000; Knuckles et al., 1997).

3.3. Dietary fibre composition of the fibre-enriched breads

As can be seen in Table 6, the TDF of the fibre-enriched breads was higher than the content of the control (no added fibre). The increase ranged from 71% with added CF to 82% with PF, compared to the control. However, the TDF content was less than expected, considering the amounts added. These results are in agreement with those previously found by Abdul-Hamid and Siew Luan (2000), after adding defatted rice bran and sugar beet fibre. They suggest that some dietary fibre could be hydrolysed by yeast enzymes or lost during baking (mainly the soluble dietary fibre). The latter explanation seems to be the right one, since the IDF content coincided with that predicted, according to the amount added, and the SDF was much less than expected. Inulin addition augmented TDF content of this fibre-enriched bread, but the increase was due to a simultaneous rise in IDF and SDF, especially in SDF.

Table 6
Effect of fibre addition on the dietary fibre composition of fibre-enriched breads

	Control[a]	Carob fibre	Inulin	Pea fibre
Total dietary fibre (%)	2.96	5.06	5.14	5.38
Insoluble dietary fibre (%)	2.42	4.67	3.14	4.94
Soluble dietary fibre (%)	0.54	0.39	2.00	0.44

[a] Control is referred to bread without added fibre.

4. Conclusion

From the overall results, it could be concluded that the addition of fibres (carob fibre, inulin and pea fibre) to wheat flour modifies the rheological properties of the dough to a in less extent than bran. The addition of those fibres increased the configuration curve ratio (P/L) and improved proofing stability was obtained with carob fibre and inulin. In addition, the bread quality characteristics were acceptable; conversely, breads enriched with CF and PF showed softer crumbs than the control.

The fibre-rich breads obtained were also considered acceptable by the sensory panel. The dietary fibre composition of the final products revealed that these fibres are good for use as fibre-enriching agents in breadmaking. Carob fibre was the product with the most promising potential in the development of fibre-rich bread in order to increase the daily fibre intake.

Acknowledgements

This study was financially supported by the European Union and Comisión Interministerial de Ciencia y Tecnología Project (FEDER, 1FD97–0671-C02–01) and Consejo Superior de Investigaciones Científicas (CSIC, Spain). Jinshui Wang would like to acknowledge the grant from the China Scholarship Council (CSC) and Agencia Española de Cooperación Internacional (AECI).

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