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Lupin, soya and triticale addition to wheat flour doughs and their effect on rheological properties

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Abstract

Full fat lupin, soya and triticale flour were added to a medium strength wheat flour. The added flour was used to replace 5 and 10% w/w of wheat flour. The effects of lupin, soya and triticale flour supplementation on physical dough properties, such as water absorption capacity, dough development time, dough stability, crumb, porosity and bread structure and quality characteristics were studied. Lupin and soya flour, at 5 and 10% substitution levels, increased the stability and the tolerance index of the dough. The volumes of the breads decreased as the level of lupin and soya flour increased due to the dilution of the gluten structure by the added protein. In the case of triticale substitution, the volumes of the breads increased as the level of triticale flour increased due to the fortification of the gluten structure by the gluten added. Nevertheless, substitution, at 5 or 10%, gives parameter values at least as good as the control sample and produce an acceptable bread, in terms of weight, volume, texture and crumb structure.

Keywords: Lupin; Soya; Triticale; Wheat flour; Rheological properties

1. Introduction

Lupin (*Lupinus albus* ssp. Graecus) is a valuable, ancient leguminous plant which grows well in different soils and climates. It is used as food by people surrounding the Mediterranean sea and by those living in the Andean highlands (Aguilera & Trier, 1978; Morrow, 1991). Soya bean (*Glycine max*) has been used in the Far East for centuries and still forms part of the indigenous diet. Modern technology has, therefore, been developed to allow for the processing of soya bean into full-fat flour, defatted flour, protein isolate, protein concentrates, texturised soya protein and spun soya protein (Circle & Smith, 1972; Wolf & Cowan, 1975). From these protein forms, new food products (Wolf & Cowan, 1975; Dendy, Clarke, & James, 1970; Dendy, 2001; De Ruite, 1978; Garcia, Torre, Marina, & L'aborda, 1997) have been developed, such as high protein cereal, snacks (Wolf & Cowan, 1975) and meat analogues (Ang, Kwik, & Theng, 1985; Horan, 1975).

Triticale (*Triticosecale wittmack*) is a type of small grain created by genetically combining wheat and rye. Triticale grains, flours, and prepared products are available through both health food and commercial outlets on a limited basis. Triticale bread and cracker products were available in the early 1980s to western Canadian consumers when triticale was grown to the advantage of farmers under wheat grain marketing programmes. Detailed studies of the nutritional composition and baking quality of triticale have been conducted during the past 20 years (Lorenz, 1982). The data indicate that while the nutritional quality of triticale is considered superior to wheat, the higher ash content, lower milling yields of flour, and inferior loaf volume and texture distract from commercial baking use of triticale. In comparison with bread wheat, triticale has low gluten content, efficient gluten viscoelasticity and, therefore, inferior bread-making quality (Peña & Ballance 1987). The potential use of triticale flour in bread-making could be more promising if it were used in blends with bread wheat flour. Rooney, Gustafson, Perez, and Porter (1969) and Unrau and Jenkins (1964) have shown that adding up to 30% triticale flour to bread wheat flour will still result in satisfactory pan-type

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bread. Even higher proportions of triticale flour can be used for the production of speciality breads (Beaux & Martin, 1985). Recent studies by Peña, Pfeiffer, Amaya, and Zacro-Hernandez (1991) and Pena and Amaya (1992) indicate that triticale flour blends of up to 50% with wheat flours produce breads with quality similar to breads made from wheat flours only.

The unique bread-making properties of wheat flour can be attributed mainly to the ability of its gluten proteins to form a viscoelastic network when mixed with water. The reduction of viscoelastic properties of a wheat flour dough, after substitution by lupin and soya flour, reduces bread-making potential. Knorr and Betschart (1978) suggested that the weakening effect of foreign proteins on wheat flour doughs was the result of a dilution of the gluten structure by the added protein. This results in lower loaf volume and subsequently has a negative affect on other quality attributes, such as crumb grain and tenderness. In the case of triticale substitution, the volumes of the breads increased as the level of triticale flour increased due to the fortification of the gluten structure by the triticale gluten added. This results in similar loaf volume and subsequently has a positive effect on other quality attributes, such as crumb and tenderness.

Consumers are becoming increasingly aware of the benefits of including a variety of cereal grains as a major portion of their diets. Increased consumption of cereals should spawn consumer interest to seek out breads and products made from cereal grains other than from common bread wheat cultivars. The key factor in producing light texture breads is gluten quality of the flour. While the desired gluten traits have been successfully obtained in common bread wheats, little or no effort has been applied to other cereal crops.

Lupin flours can be an excellent choice for improving the nutritional value of bread (Dervas, Doxastakis, Hajisavva-Zinoviadi, & Triantafillakos, 1999; Doxastakis, 2000). The high lysine, low methionine content complements that of wheat flour proteins, which are poor in lysine and relatively higher in the sulphur-containing amino acids (Bloksma & Bushuk, 1988). In lupins, the main limiting amino acids are methionine and cystine, followed by valine and then tryptophan. Since lupins are legumes, the lack of sulphur-containing amino acids is not surprising. Valine seems to be adequate in *L. albus* (Aguilera & Trier, 1978). Lupin protein isolates, prepared on a bench scale, have been shown to have good nutritional properties when supplemented with methionine or mixed with cereals (Pompei & Lucisano, 1976; Ruiz & Hove, 1976). Studies have shown that lupin flour can be successfully incorporated into products (Hung, Papalois, Nithianandan, Jiang, & Versteeg, 1990; Pompei, Lucisano, & Ballini, 1985) at up to 20% inclusion, to produce products that rate higher in terms of colour, texture, taste and overall acceptability than the control. A number of pasta products containing lupin flour are currently available on the domestic market. Also, lupin can be incorporated at up to the 50% level in biscuits (Kyle, 1994).

Soyabean flours are increasingly being used in many countries because they are a good source of vegetable proteins, with a low fat content. The nutritional value of the soyabean is not the only factor enhancing its consumption, as it plays and important role in health (Steinke, 1992). All nine of the essential amino acids required by humans can be found in the amino acid composition of soyabean. A digestibility of 95–100% has been found in isolated soyabean protein in evaluations of animals and humans (Steinke, 1992). Moreover, the essential amino acid content in soyabean exceeds the amino acid requirements of children and adults, which confirms the protein quality of this vegetable (Steinke, 1992).

Lysine, which is the first limiting amino acid in wheat, is present in larger amounts in triticale. The differences in lysine between wheat and triticale do not seem significant, however, since lysine depends on the variety. Milling of triticale results in fractions of different protein and amino acid contents. Lysine and leucine contents decrease as particle sizes of air-classified fractions increase, with corresponding increases in methionine and phenylalanine. From the essential amino acid pattern of a triticale concentrate, grain, flour, and bran, in comparison with the FAO pattern, only the concentrate meets the FAO lysine recommendation (Lorenz, 1982). The high consumption of bread can be used as a vehicle for the distribution of supplementary quantities of protein to the population, hoping to improve the nutritional value of the diet.

The purpose of this investigation was to study the effects of the addition of full fat lupin, soya and triticale flour to a medium strength wheat flour. The added flour was used to replace 5 and 10% w/w. Physical dough properties, such as water absorption capacity, dough development time, dough stability, as well as crumb, porosity and bread structure and quality characteristics, were studied. The traditional bread-making procedure has been used for the utilization of wheat–lupin–soya–triticale composite flours. Dough consistency, fermentation period and incorporation of a dough conditioner were considered and their effects on the quality parameters of the bread were evaluated.

2. Material and methods

2.1. Raw materials

Lupin seeds (*L. albus* ssp. Graecus) were obtained from a Greek grower (Village Kato Metohi, Lassithi, Krete). Soya bean (*G. max*) was obtained from

NAGREF, Cereal Institute, Thermi, Thessaloniki, Greece. Ttiticale (*T. wittmack*) was obtained from NAGREF, Cereal Institute, Thermi, Thessaloniki, Greece.

All seeds were dehulled and ground in a laboratory mill, model 3100, Sweden to pass a 0.8-mm screen. The produced flour was added at 5% and 10% substitution levels.

The following flour products were used for addition to wheat flour (WF) doughs (Table 1): full-fat lupin flour (LF), full-fat soya flour (SF) and full-fat triticale flour (TF)

2.2. Chemical analysis

Nitrogen content was determined by using the Kjeldahl method and was multiplied by a factor of 5.7 to determine protein content in wheat and lupin and 6.25 to determine protein in soya (Hudson, Fleetwood, & Zand-Moghaddam, 1976). Moisture content was determined by drying the samples at 105 °C to constant weight. All the determinations, such as fat, moisture and ash, were expressed on a dry weight basis and nitrogen was determined according to the official methods (AOAC, 1975).

2.3. Farinograph procedure

The dough mixing properties of the different wheat-lupin-soya-triticale flour blends were examined with the Brabender farinograph (Brabender, Duisburg, Germany) according to the constant flour weight procedure (AACC, 1983; ICC, 1992). Dough development time was defined as the time to the point of the curve immediately before the first sign of decrease in consistency. The maximum consistency was defined as the consistency in BU, measured at the development time and in the middle of the curve bend, while the dough stability was defined as the drop of the curve (BU) during the first 2 min after dough development time.

Table 1
Proximate chemical composition of wheat flour (WF), lupin flour (LF), soya flour (SF), and triticale flour (TF)

Constituent[a] (%)	WF	LF	SF	TF
Moisture	12.6	7.8	7.4	13.4
Ash	0.61	1.47	5.10	0.44
Protein[b]	11.7	32.0	39.3	12.5
Fat	2.6	15.1	24.5	5.3
Polysaccharides (by difference)	72.5	43.6	23.7	68.4

[a] Expressed on a dry matter basis. Values are averages of three repetitions.

[b] N × 5.7 for WF, LF, TF, and N × 6.25 for SF.

2.4. Extensograph procedure

Doughs from the farinograph measurements were cut into two parts of 150 g each and passed through the balling and moulder unit of a Brabender extensograph (Brabender, Duisburg, Germany). After 45 min resting in the fermentation cabinet, the dough was stretched. After this first test, the balling and moulding operations were replated and the doughs were tested again after a further 45 min resting time. The same procedure was repeated for a third time, following the offical procedure (AACC, 1983; ICC, 1992).

The results were expressed as the resistance to constant deformation after 50 mm stretching (R_{50}); the extensibility (E_x) was described as the distance travelled by the recorder paper from the moment that the hook touches the test piece until rupture of the test piece and the ratio between the two of them (R_{50}/E_x).

2.5. Baking test

Experimental bread-making was done according to the Cereals Institute procedure as described below (Boudonas, Pattakou, Papastefanou, & Gioupsanis, 1976). The baking formula, based on 300 g (14%) of flour weight, was: flour 295.2 g, salt 6 g, fresh compressed yeast 5 g. The wheat flour was subsituted by lupin, soya and triticale flour at levels of 5 and 10%.

Flours (or flour blends) were stirred for 1 min in the farinograph bowl; after this period, the other ingredients (salt and yeast), previously dissolved separately in some water, and the remaining water, were added. The amount of water to be used was determined by the farinograph absorption value.

The dough was then mixed for 5 min in all flour or flour blends and placed in baking pans and fermented at 30 °C and 80–90% relative humidity. Then the dough was re-mixed and was replaced for re-fermentation. The above two fermentation periods were 45 min in both cases. Baking for each 400 g dough piece was at 220 °C for 45 min. During baking, some water was vapourized in the oven to avoid any extreme dryness of the bread crust. Specific loaf volume was measured by rapeseed displacement after cooling.

3. Results and discussion

3.1. Mixing properties of the wheat–lupin–soya–triticale flour blends

The chemical compositions of flours are shown in Table 1. The results of the farinogram and extensogram studies are shown in Table 2. The amount of water (absorption) required to centre the farinogram curve on the 500 BU (Brabender Units) line increased steadily with every increment of flour blends from 56.5 WF and 52.6 TF for 5% WLF to 60.3 and, for 10% WLF, to 63.5, for 5% WSF to 57.2 and for 10% WSF to 57.9, for 5% WTF to 56.6 and for 10% WTF to 56.4.

The presence of lupin–soya–triticale flours increased the water required for the optimum bread-making absorption. Water absorption level was positively correlated with loaf volume, and was highly significant (Table 2) in all cases investigated. Water absorptions were evaluated up to levels at which the doughs were rather sticky. Although such absorptions resulted in larger loaf volumes, these water levels could not be considered optimal because the workability of the doughs was impaired. The same trend was observed with the extensograph and specific values, too. The valorimetric values (BU) showed an increase as the substitution level increased from 5 to 10% w/v and were negatively correlated with loaf volume. Similar effects have been previously reported for lupin isolate (Kramer & Twigg, 1970), lupin flour (Ballester, Castro, Cerda, Carcia, & Yanez, 1988; Eldash & Campos, 1980; Lucissano & Pompei, 1981; Witting de Penna, Carreno, Urutia, Lopez, & Ballester, 1987), corn flour (Navickis, 1987), soya and sunflour (Fleming & Sosulski, 1977) and navy bean flour (Lorimer, Zabik, Harte, Stachiw, & Uebersax, 1991a, 1991b).

Development time is the time from the first addition of water to the time the dough reaches the point of greatest torque. During this phase of mixing, the water hydrates the flour components and the dough is developed. Dough-mixing studies showed that inclusion of lupin, soya and triticale flour blends delayed farinograph arrival time and decreased dough stability when substituted for wheat flour in a bread system. As the level of flour blends in composite doughs increased, farinograph absorption (Table 2) and mixing tolerance index (Fig. 1) increased, but mixing time and dough stability decreased as the substitute level increases from 5 to 10% and from lupin to soya and to triticale.

Extensographs showed that E_x required to break the strength of dough after 45, 90 and 135 min in the rest cabinets decreased as the substituted level and the resting time increased from 5 to 10% and from 45 to 135 min, respectively (Fig. 2). The ratio R_{50}/E_x increased as the proportion of wheat substitution changed from lupin, soya to triticale and appeared to be more pronounced after 90 min of resting time.

The valorimeter values (BU), which represent the physico-mechanical properties of the dough, were not all over the minimum acceptable 40BU, according to the International Cereal Chemistry (ICC, 1992). Only the lupin flour addition substantially increased the valorimeter values in comparison with all other flour blends which are on the border line.

3.2. Baking and crumb structure

Substitution of WF by flour blends resulted in decreases of dough and bread yield (g/100 g of flour) in the cases of lupin and soya and an increase in triticale. Water absorption (Table 3) and re-mixing time increased. Loaf volume (cm^3 /100 g of flour) decreased in the case of lupin and soya incorporation and increased with triticale addition. The lower values of the above parameters could be attributed to the dilution of the wheat gluten structure by the legume-treated protein. Only the addition of triticale flour seems to improve the parameter values, due to its gluten structure.

Typical loaves are obtained with or without substitution of WF by LF, SF and TF at 5 and 10% levels (Fig. 3). In baking experiments (Table 3), loaf volumes of breads prepared with lupin and soya flour substitutes

Table 2
Farinogram and extensogram characteristics of flour and flour blends of wheat flour (WF), triticale flour (TF), wheat-lupin flour (WLF), wheat-soya flour (WSF), wheat- triticale flour (WTF)

Flour and flour in blends (%)	Water absorption (%)	Valorimeter vaule (BU)	Resting time					
			45 min		90 min		135 min	
			E (cm^2)[a]	R_{so}/E_x[b]	E (cm^2)[a]	R_{so}/E_x[b]	E (cm^2)[a]	R_{so}/E_x[b]
100% WF	56.5	41	89	2.35	99	3.08	120	2.98
100% TF	52.6	33	34	0.99	31	1.09	29	1.11
95% WF + 5% LF (WLF)	60.3	48	83	2.24	92	2.25	87	3.14
90% WF + 10% LF (WLF)	63.5	65	51	2.46	69	3.26	58	3.14
95% WF + 5% SF (WSF)	57.2	37	101	2.71	102	3.41	97	3.43
90% WF + 10%SF (WSF)	57.9	40	88	1.96	95	2.44	103	3.38
95%WF + 5%TF (WTF)	56.6	42	100	1.98	112	2.40	116	3.45
90%WF + 10%TF (WTF)	56.4	41	98	1.77	104	2.78	110	2.85

[a] Energy (E) required to break the strength of dough after 45, 90 and 135 min in the rest cabinets of the Extensograph.
[b] Resistance (R) measured after 50 mm transposition of the recorded paper. Extensibility (E_x) of dough in mm.

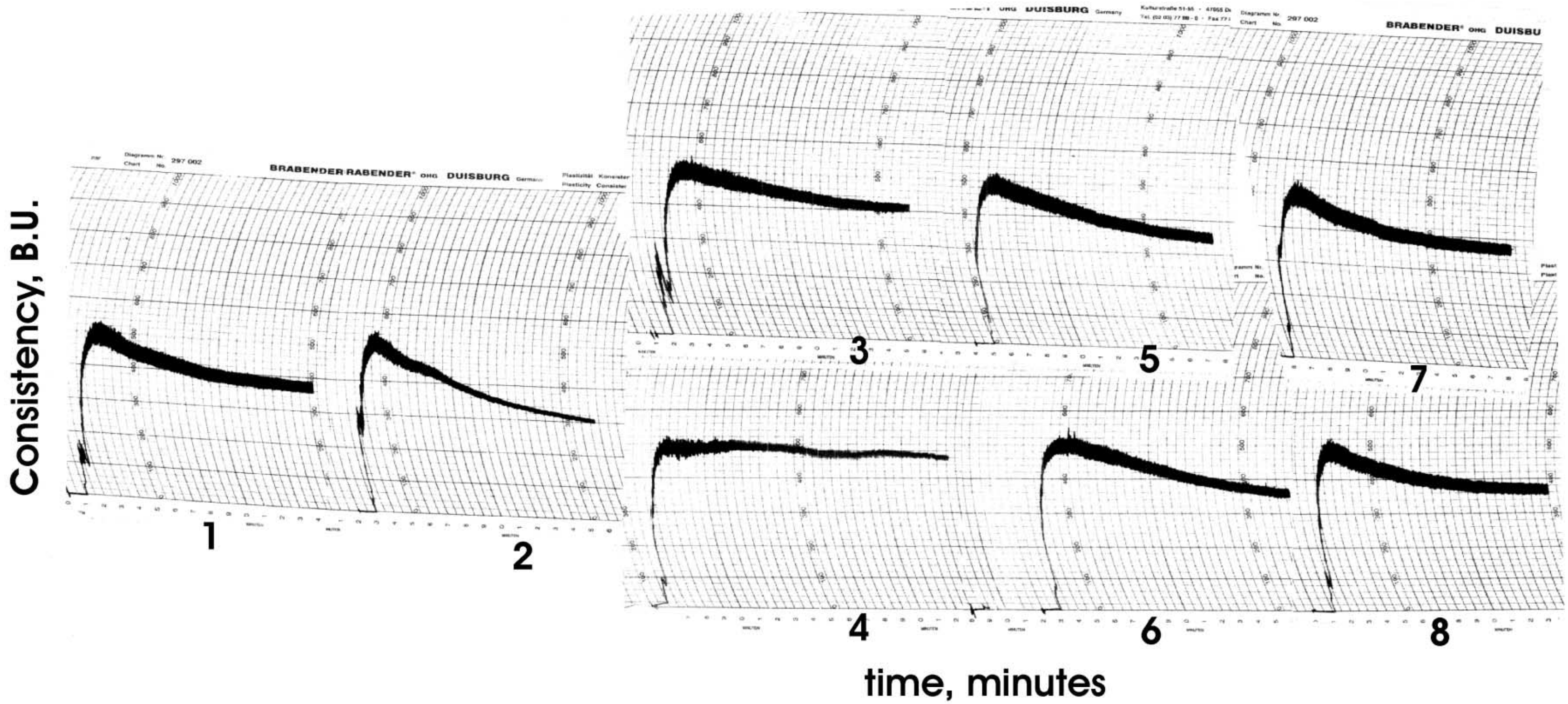

Fig. 1. Farinograms of wheat flour (WF), triticale flour (TF), wheat–lupin flour (WLF), wheat–soya flour (WSF) and wheat–triticale flour (WTF) blends: (1) 100% wheat flour; (2) 100% triticale flour; (3) 95% wheat flour and 5% lupin flour; (4) 90% wheat flour and 10% lupin flour; (5) 95% wheat flour and 5% soya flour; (6) 90% wheat flour and 10% soya flour; (7) 95% wheat flour and 5% triticale flour; (8) 90% wheat flour and 10% triticale flour.

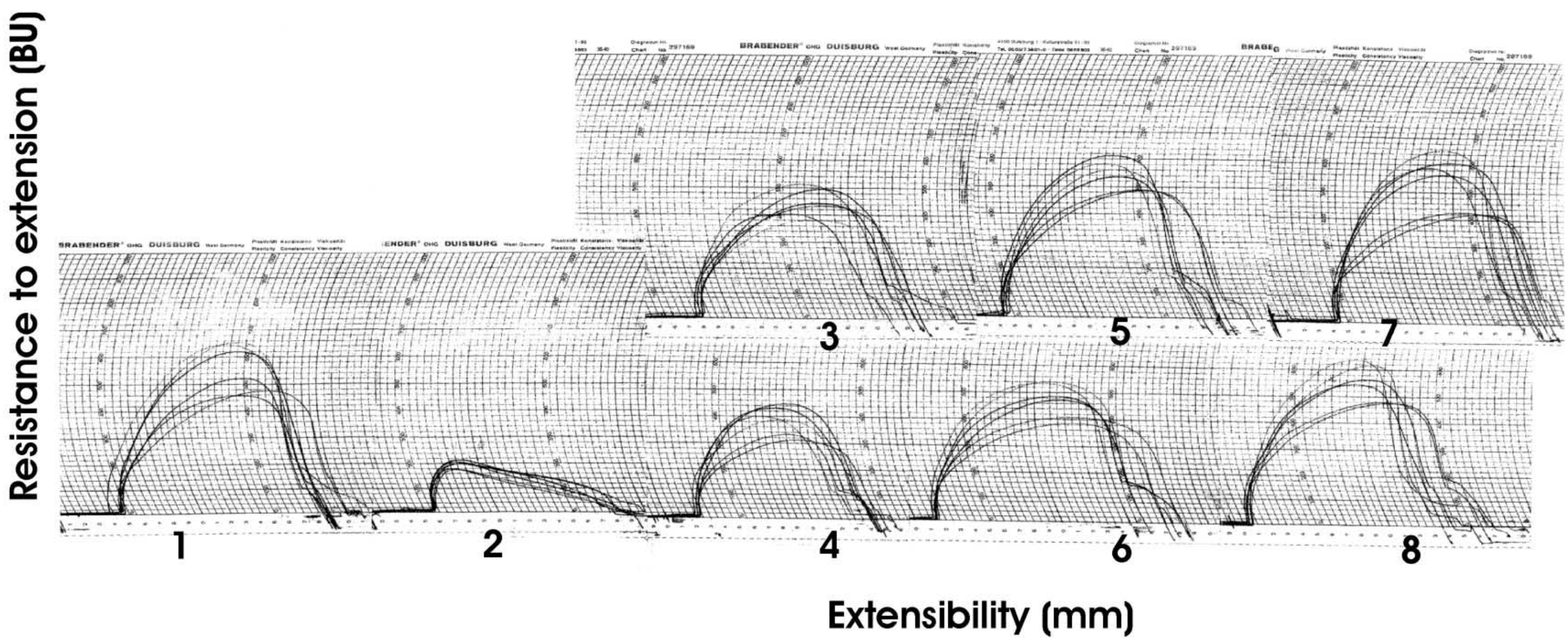

Fig. 2. Extensograms of wheat flour (WF), triticale flour (TF), wheat–lupin flour (WLF), wheat–soya flour (WSF) and wheat–triticale flour (WTF) blends at 45, 90 and 135 min. (1) 100% wheat flour; (2) 100% triticale flour; (3) 95% wheat flour and 5% lupin flour; (4) 90% wheat flour and 10% lupin flour; (5) 95% wheat flour and 5% soya flour; (6) 90% wheat flour and 10% soya flour; (7) 95% wheat flour and 5% triticale flour; (8) 90% wheat flour and 10% triticale flour. Extensograms show tracings for each fermentation period.

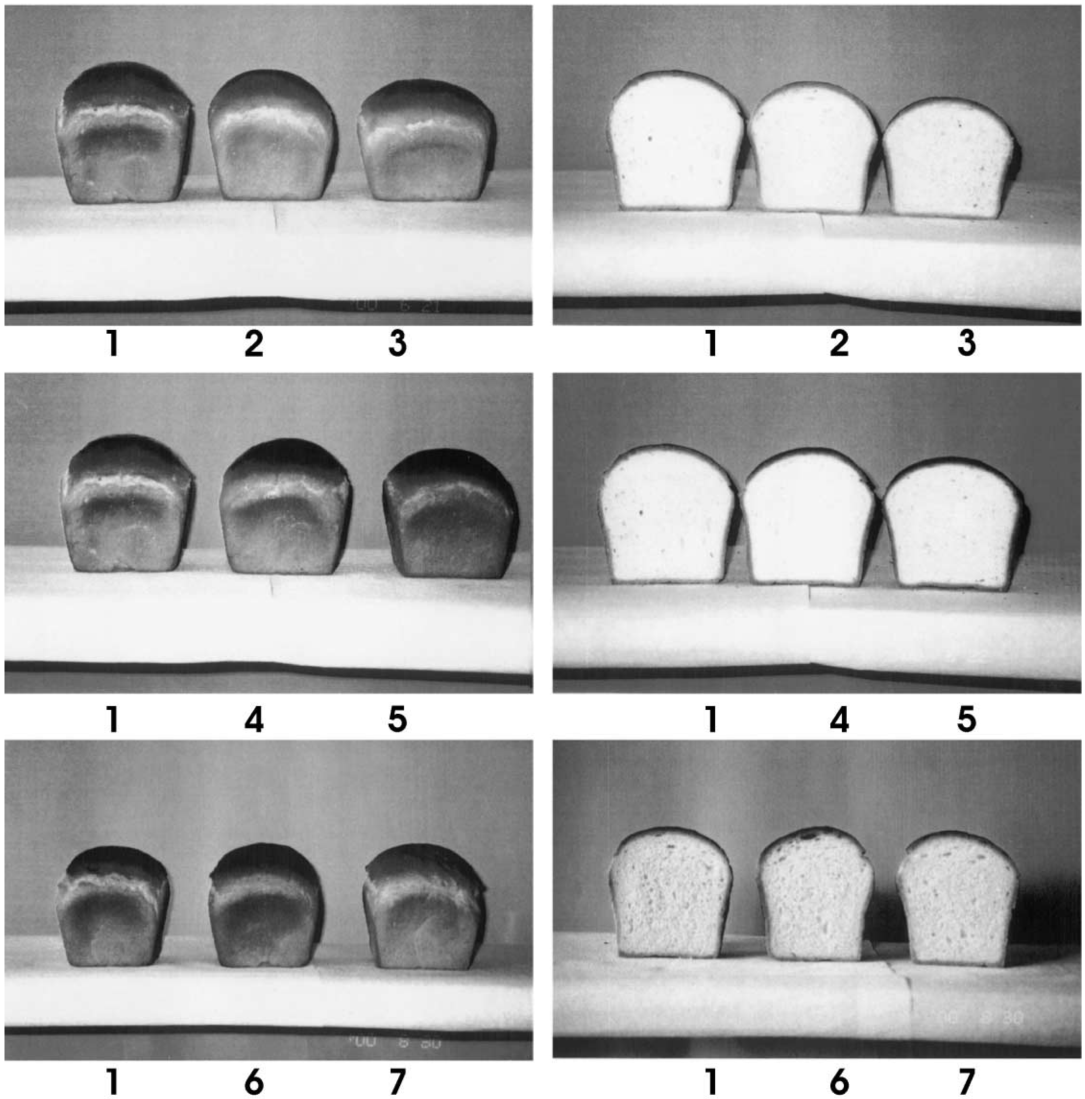

Fig. 3. Loaf volume and crumb structure of breads containing different levels of lupin–soya and triticale: (1) 100% wheat flour; (2) 95% wheat flour and 5% lupin flour; (3) 90% wheat flour and 10% lupin flour; (4) 95% wheat flour and 5% soya flour; (5) 90% wheat flour and 10% soya flour; (6) 95% wheat flour and 5% triticale flour; (7) 90% wheat flour and 10% triticale flour.

Table 3
Experimental baking test values

Flour and flour in blends (5)	Water absorption (%)[a]	Specific volume (cm^3/100 g)[a]
100% WF	56.5	340.9
100% TF	52.6	286.7
95% WF+5%LF	60.3	311.2
90%WF+10%LF	63.5	280.3
95%WF+5%SF	57.2	315.9
5%WF+10%SF	57.9	300.2
95%WF+5%TF	56.6	386.4
90%WF+10%TF	56.4	385.7

[a] Averages of triplicate baking experiments.

decreased, crust colour darkened, crumb colour became more yellow and crumb texture showed evidence of thickened cells. In the case of the triticale flour substitute, the loaf volume increased and the crumb structure characteristics were satisfactory.

Various researchers have investigated the use of lupin (Kyle, 1994), soya (Lusas & Riaz, 1995) and triticale (Peña & Amaya, 1992) flours in a substitutional role in variety of cereal products. The yellow colours of the legume flours have a considerable appeal and would be of value in many goods and in pasta and noodle dishes. Most people who have tried lupin-wheat flour (Dervas et al., 1999; Kyle, 1994), soya-wheat (Lusas & Riaz,

1995) and triticale-wheat (Peña & Amaya, 1992) mixes have found the texture, taste, and frequently the colour, to be appealing.

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