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# Lupin flour addition to wheat flour doughs and effect on rheological properties

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**Abstract**

Full fat lupin flour (FFLF), concentrated lupin flour (CLF) and defatted concentrated lupin flour (DCLF) of *Lupinus albus* ssp. Graecus was added to a medium strength wheat flour. The lupin flour was used to replace 5, 10 and 15% of wheat flour. The effects of lupin flour supplementation on physical dough properties, crumb and bread structure and quality characteristics were studied. Lupin flour, at 5% substitution level, increased the stability and the tolerance index of the dough, while a marked weakening was noted at higher levels (15%) of supplementation. The volumes of the breads decreased as the level of lupin flour increased; nevertheless, substitution at 5 or 10% by CLF and DCLF gives parameter values at least as good as the control sample and produces an acceptable bread in terms of weight, volume, texture and crumb structure. 

## 1. Introduction

Lupin (*Lupinus albus* ssp. Graecus) is a valuable ancient leguminous plant which grows well in different soils and climates. It has been used as food by people around the Mediterranean area and by those living in the Andean highlands (Aguilera & Trier, 1978; Morrow, 1991).

The unique breadmaking 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 flour, reduces breadmaking 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.

Lupin flours can be an excellent choice for improving the nutritional value of bread. 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 (Ruiz & Hove, 1976; Pompei and Lucisano, 1976).

Functional properties of proteins, such as solubility, water absorption and binding, viscosity, gelation, cohesion-adhesion, elasticity, emulsification, fat absorption, flavour binding, foaming and colour control (Kinsella, 1979) are influenced by agronomic factors, storage, composition and processing (Cherry, Mc Watters, & Beuchat, 1979). Although carbohydrate is the major component of legumes the protein component has received considerably more attention (Mc Watters, 1990).

The use of vegetable proteins as functional ingredients in foods depends mainly on the benefits that they can produce (Mc Watters & Cherry, 1977; Kyle, 1994). Taking into consideration actual developments in the food industry, the lupin flour and its products might represent a useful raw material. Its use will depend upon its functional properties in order to find possible applications in food products.

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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. Lupin flour is also being tested as a base for a vermicelli-like product. Also, lupin can be incorporated at up to 50% level in biscuits (Kyle, 1994).

The purpose of this investigation was to study the effects of extraction methods and solvent used on the functionality of lupin products and effects of lupin flour incorporation on the physical properties of the dough and the quality characteristics of lupin–wheat bread. The traditional bread-making procedure has been used for the utilization of wheat–lupin 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. Materials and methods

### 2.1. Raw materials

Lupin seeds (*Lupinus albus* ssp. Graecus) obtained from a Greek grower (Lasithi, Krete) were dehulled and ground in a Kainas-mill, model 860-A, Sweden to pass a 0.5 mm screen.

The following lupin products (Alamanou & Doxastakis, 1995a,b, 1997) were used for addition to wheat flour (WF) doughs (Table 1).

1. The full fat lupin flour (FFLF).
2. The concentrated lupin flour (CLF). FFLF was suspended in methanol (25% v/w) solution at a 1:5 ratio. The slurry was kept with periodical stirring for 45 min at ambient temperature and the product was centrifuged at 500 ***g***. The supernatant was discarded and the residue was collected and freeze-dried. To prepare protein concentrates of higher protein contents it was necessary to further process flours to remove some of the low-molecular-weight components. Protein concentrates were obtained by removing the water-soluble sugars, ash, and other minor constituents of flours. In the process used the nonprotein constituents were extracted with aqueous alcohol, leaving the proteins and polysaccharides which were desolventized and freeze-dried to yield the concentrate.
3. The defatted concentrated lupin flour (DCLF). CLF was defatted with *n*-hexane (1:4 w/v). The slurry was kept, with periodical stirring for 45 min, at ambient temperature and the *n*-hexane with fat was decanted. The procedure was repeated twice and the lupin product was dried in an air stream. All the extracted flour was then sifted with a 3 mesh sieve. A commercial WF of medium strength was used in all baking experiments.

Table 1
Proximate chemical composition of wheat flour (WF), full fat lupin flour (FFLF), concentrated lupin flour (CLF) and defatted concentrated lupin flour (DCLF)

| Constituent[a] (%) | WF[b] (%) | FFLF[b] (%) | CLF[b] (%) | DCLF[b] (%) |
|---|---|---|---|---|
| Moisture | 14.8 | 7.1 | 6.4 | 10.2 |
| Ash | 0.7 | 2.9 | 2.8 | 2.2 |
| Protein (N×5.7) | 10.9 | 30.6 | 36.3 | 32.6 |
| Fat | 1.4 | 9.4 | 6.4 | 3.7 |
| Polysaccharides (by difference) | 72.2 | 50.0 | 48.1 | 51.3 |

[a] Data are reported on a dry matter basis.
[b] Values are averages of three repetitions.

### 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 WF, FFLF, CLF, DCLF flours (Hudson, Fleetwood, & Zand-Moghaddam, 1976). Protein content was expressed on a dry weight basis. Moisture content was determined by drying the samples at 105°C to constant weight. All the determinations such as fat, moisture, 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 flour blends were examined with the Brabender farinograph (Brabender, Duisburg, Germany) according to the constant flour weight procedure (AACC, 1983; IACC, 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 width, while the dough stability was defined as the drop of the curve (BU) during the first 2 min after dough development time.

### 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 repeated and the doughs were tested again after a further 45 min resting time. The same procedure was repeated for a third time, following the procedure (AACC, 1983; IACC, 1992).

The results were expressed as the resistance to constant deformation after 50 min 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 Cereal's Institute procedure as described below (Boudonas, Pattakou, Papastefanou, & Gioupsanis, 1976. The baking formula, based on 400 g of flour weight, was: flour 400 g, salt 8 g, fresh compressed yeast 6.8 g. The wheat flour was substituted by lupin flour at levels of 5, 10 and 15%.

Flour (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 400 g was placed 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 vaporized 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. Effect of extraction solvents on the functionality

This study is concerned with the effect of extraction on the functionality of lupin products and the effects of lupin flour incorporation on the physical properties of the dough and the quality characteristics of the lupin– wheat bread.

Several factors and processing steps affect the functional properties of proteins. Both intrinsic properties and applied processing conditions influence the observed functional properties of proteins. The inherent molecular properties of the protein (size, shape, conformation), the methods and conditions of isolation (refining, drying, storage) and the degree of purification (processing alterations) all influence performance in food systems (Mc Watters, 1990; Kinsella, 1979). The protein content of flour is extremely important because almost all flour properties (water absorption, mixing requirement, mixing tolerance, dough handling characteristics, oxidation requirements, loaf volume and even bread crumb grain) are highly correlated with protein content (Pomeranz, 1985).

The method of fat extraction used can have a marked effect on the lupin flour properties. The solvent, *n*-hexane, used for fat extraction in the DCLF, markedly affects functionality by removing apolar lipids such as triglycerides and excluding polar lipids such as fatty acids and phospholipids.

The solvent, methanol, used for fat extraction in the CLF, also markedly affects functionality by excluding apolar lipids. Triglycerides solubility in alcoholic solvents increases with the chain length of the hydrocarbon moiety of the alcohol so they are generally more soluble in ethanol and completely insoluble in *n*-butanol.

Similarly, the shorter the chain length of the fatty acid residues, the greater solubility of the lipid in more polar solvents; tributyrin is completely soluble in methanol, while tripalmitin is virtually insoluble in this solvent. Polar lipids, on the other hand, may be only sparingly soluble in hydrocarbon solvents unless solubilised by association with other lipids, but they dissolve readily in more polar solvents such as methanol, ethanol or chloroform (Conkerton, Wan, & Richard, 1995; Dahmer, Fleming, Collins, & Hildebrand, 1989; Nash & Frankel, 1986; Christie, 1982; Pomeranz, Shogren, & Finney, 1968). However, lupin protein has high water and oil absorption characteristics and exhibits better solubility, whippability and comparable emulsification capacity to soy protein (Alamanou & Doxastakis, 1997; Kiosseoglou & Perdikis, 1994; Kyle, 1994)

### 3.2. Optimal mixing time and water absorption

The chemical compositions of WF and the lupin flour products 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 FFLF from 56.2 for 5% to 59.5 for 15%, of CLF from 57.9 for 5% to 66.0 for 15% and of DCLF from 56.7 for 5% to 64.4 for 15%.

The presence of lupin flour products increased the water required for the optimum breadmaking absorption. Water absorption level was positively correlated with loaf volume, and it was highly significant 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. Similar effects have been previously reported for lupin isolate (Kramer & Twigg, 1970), lupin flour (Eldash & Campos, 1980; Lucisano & Pompei, 1981; Witting de Penna, Carreno, Urutia, Lopez, & Ballester, 1987; Ballester, Castro, Cerda, Carcia, & Yanez, 1988), corn flour (Navickis, 1987), soy and sunflour (Fleming & Sosulski, 1977), navy bean flour (Lorimer, Zabik, Harte, Stachiw, & Uebersax, 1991a,b).

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 flour blends delayed farinograph arrival time and decrease dough stability when substituted for wheat flour in a bread system. As the level of lupin flour in composite doughs increased, farinograph absorption (Table 2) and mixing tolerance index (Fig. 1) increased for FFLF to CLF and is more pronounced to DCLF, but mixing time and dough stability decreased as the substituted level increases from 5 to 15%.

Extensographs showed that $E_x$ required to break the stength 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 15% and from 45 to 135 min,

Table 2
Farinogram and extensogram characteristics of blends of wheat flour (WF), full fat lupin flour (FFLF), concentrated lupin flour (CLF) and defatted concentrated lupin flour (DCLF)

| Lupin flour in blend (%) | Water absorption (%) | Valorimeter value (BU) | Resting time | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 45 min | | 90 min | | 135 min | |
| | | | $E^a$ (cm$^2$) | $R^b_{50}/^cE_x$ | $E^a$ (cm$^2$) | $R^b_{50}/^cE_x$ | $E^a$ (cm$^2$) | $R^b_{50}/^cE_x$ |
| WF | 53.0 | 55 | 60 | 1.07 | 60 | 1.02 | 54 | 1.05 |
| FFLF (5) | 56.2 | 59 | 50 | 1.03 | 56 | 1.28 | 48 | 1.11 |
| FFLF (10) | 58.9 | 53 | 40 | 1.11 | 36 | 1.20 | 33 | 0.98 |
| FFLF (15) | 59.5 | 48 | 35 | 1.23 | 31 | 1.53 | 28 | 1.42 |
| CLF (5) | 57.9 | 69 | 58 | 1.44 | 56 | 1.55 | 52 | 1.48 |
| CLF (10) | 62.0 | 68 | 65 | 1.94 | 65 | 2.40 | 61 | 2.10 |
| CLF (15) | 66.0 | 61 | 48 | 1.69 | 52 | 1.98 | 46 | 1.76 |
| DCLF (5) | 56.7 | 58 | 70 | 1.52 | 72 | 1.70 | 70 | 1.91 |
| DCLF (10) | 61.0 | 58 | 73 | 1.81 | 78 | 2.54 | 70 | 2.83 |
| DCLF (5) | 64.4 | 55 | 59 | 2.26 | 56 | 3.24 | 54 | 3.40 |

[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.
[c] Extensibility ($E_x$) of dough in mm.

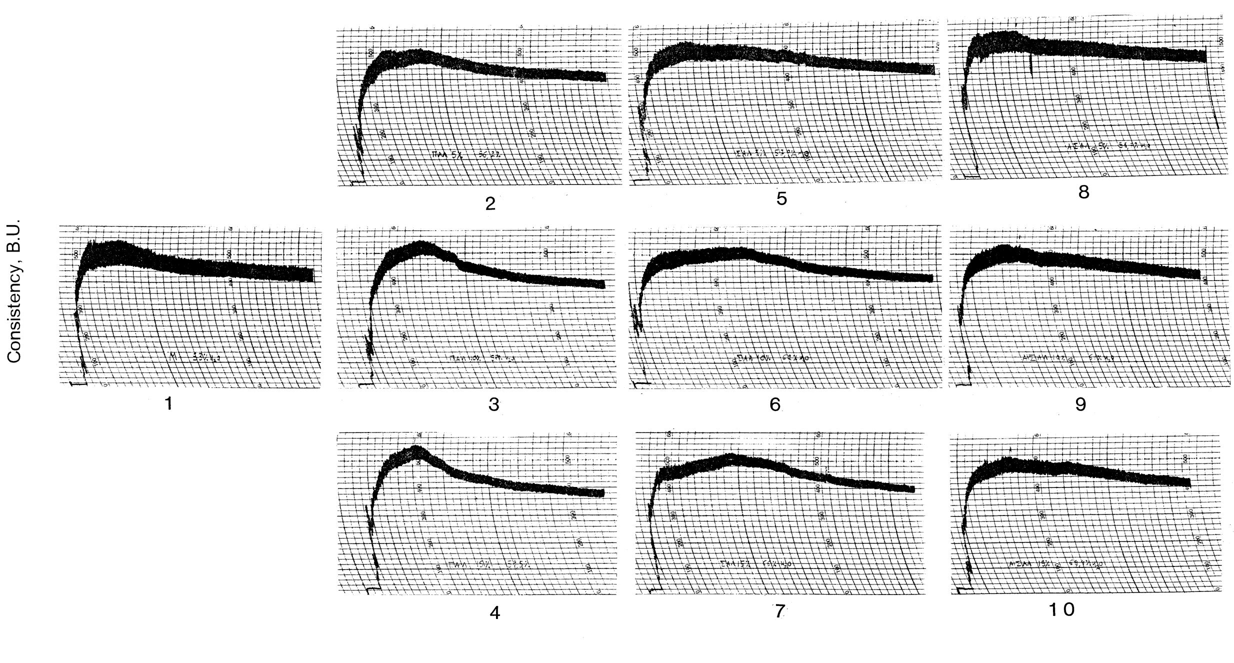


Fig. 1. Farinograms of wheat flour and wheat flour–lupin flour blends. (1) 100% WF; (2–4) 5%, FFLF, CLF, DCLF; (5–7)10% FFLF, CLF, DCLF; (–10) 15% FFLF, CLF, DCLF.

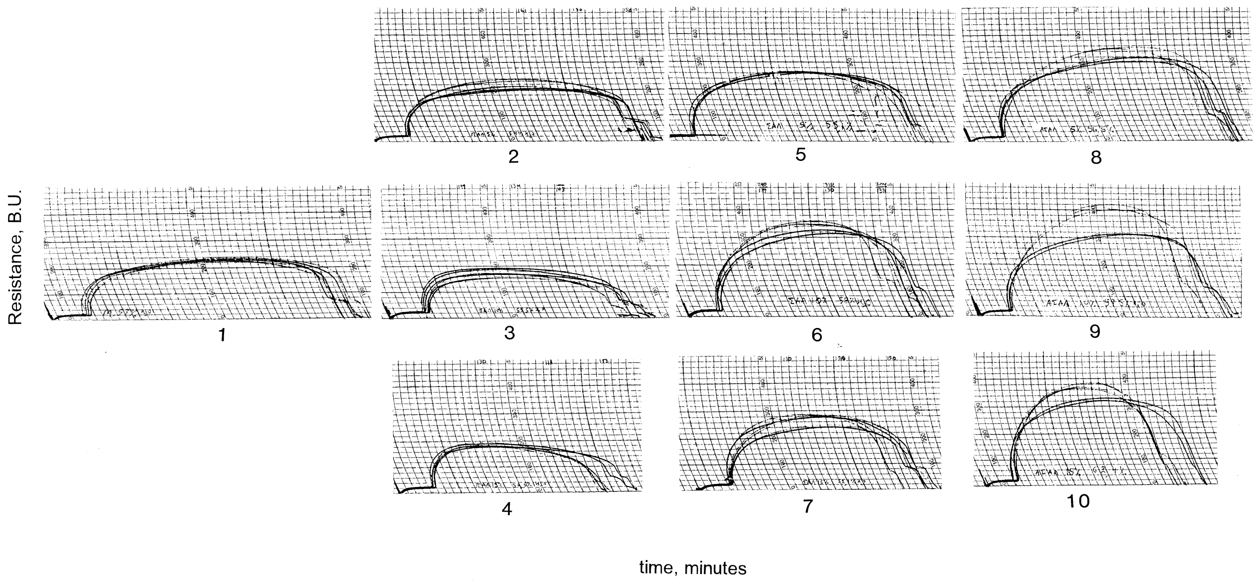


Fig. 2. Extensograms of wheat flour and wheat flour–lupin flour blends at 45, 90 and 135 min. (1) 100% WF; (2–4) 5%, FFLF, CLF, DCLF; (5–7) 10% FFLF, CLF, DCLF; (8–10) 15% FFLF, CLF, DCLF. Extensograms shows tracings for each fermentation period.

respectively (Fig. 2). The ratio $R_{50}/E_x$ increased as the proportion of wheat substitution changed from FFLF, CLF to DCLF and appears to be more pronounced after 90 min of resting time.

The valorimeter values (BU), which represent the physico-mechanical properties of the dough, were all over the minimum acceptable 40 BU, according to the International Association for Cereal Chemistry (IACC, 1992).

Substitution of WF by lupin flour products resulted in increase of dough and bread yielding (g/100 g of flour) and in an increase of water absorption (Table 3) re-mixing time and loaf volume ($cm^3$/100 g of flour). The lower values of the above parameters could be attributed to the dilution of the wheat gluten structure by the added protein.

Sensory evaluation studies indicate that various forms of lupin can be used satisfactorily as a food ingredient in a wide range of foods but that many recipes need modification because of the unique properties of lupin. Lupin in various forms was judged to be acceptable to consumers as a base for Tempeh, as a filler in Spring Rolls and Meat Pies, and an ingredient in Pasta, some desserts, vegetable soups, loaves and biscuits (Flanagan, 1994; Nottage & Wallace, 1994). Also, the use of lupin in food applications has been investigated by researchers in sprouts, tempeh, miso, soy sauce, tofu, beverages, pasta, bread, baked goods and in snack foods (Kyle, 1994).

### 3.3. Baking and crumb structure

As mentioned previously, the various solvents cause changes in the lupin products. It is the quantity and the quality of the remaining substances which inevitably alter the baking properties and crumb structure.

Typical loaves are obtained with or without substitution of WF by DCLF, CLF and FFLF at 5, 10 and 15% levels (Fig. 3). In baking experiments (Table 3), loaf volumes of breads prepared with lupin protein substituted for wheat flour decreased, crust colour darkened, crumb colour became more yellow and crumb texture showed evidence of thickened cells. Although crumb structures were not drastically impaired upon substitution of wheat flour by 10 or 15% of the title compounds, the decrease in loaf volumes was more marked. It was clear that all lupin flours impaired loaf volume to a larger extent by 15% substitution.

Table 3
Experimental baking test values[a]

| Lupin flour in blend (%) | Water absorption (%) | Specific volume ($cm^3$/100 g) |
|---|---|---|
| WF | 53.9 | 390.1 |
| FFLF | 54.4 | 355.7 |
| FFLF | 55.0 | 335.3 |
| FFLF | 56.0 | 316.0 |
| CLF | 55.8 | 374.8 |
| CLF | 57.7 | 375.3 |
| CLF | 61.0 | 329.4 |
| DCLF | 56.5 | 382.5 |
| DCLF | 59.2 | 366.5 |
| DCLF | 62.0 | 327.3 |

[a] Averages of triplicate baking experiments.

Various researchers have investigated the use of lupin flour in a substitutional role in a variety of cereal-based products. The yellow colour of the flour has considerable appeal and would be of value in many goods and in pasta and noodle dishes. Most people who have tried lupin–wheat flour mixes have found the texture, taste and frequently the colour to be appealing (Kyle, 1994).

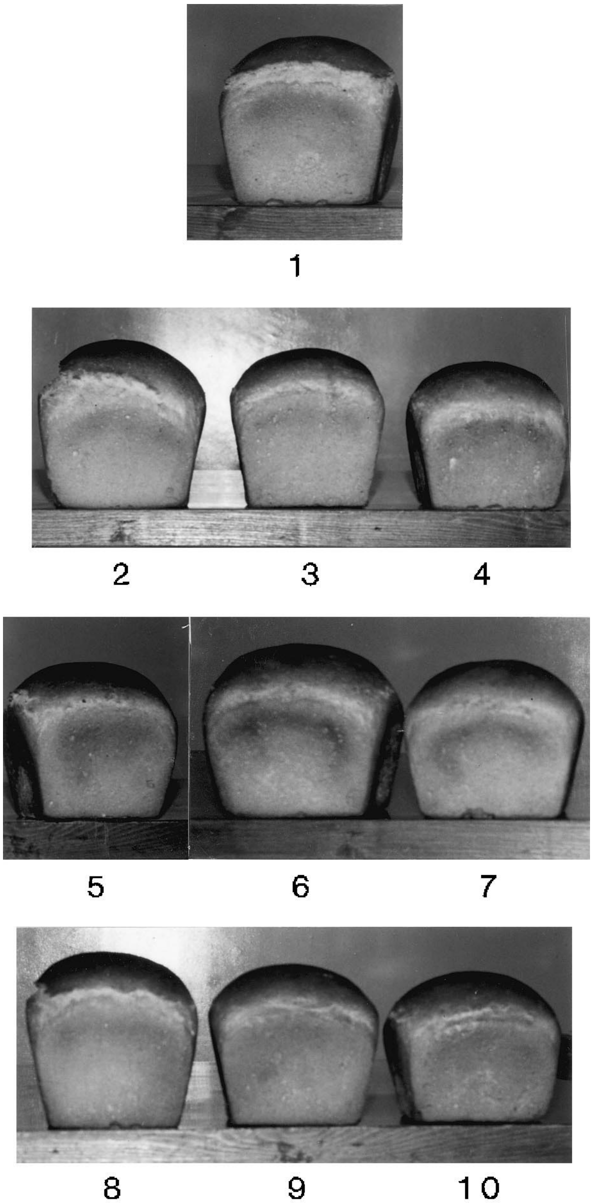


Fig. 3. Bread containing different levels of lupin flour proportions of wheat flour to lupin flour. (1) 100% WF; (2–4) 5%, 10%, 15% DCLF; (5–7) 5%, 10%, 15% CLF; (8–10) 5%, 10%, 15% FFLF.

The inclusion of lupin flour at up to 4% in white and wholemeal breads was shown to produce a small increase in loaf weight, due to higher water absorption, and to provide an extended shelf-life. The acceptability of these products was high (Petterson & Crosbie, 1989). Lupin flour can be used at up to 10% inclusion in breads without affecting baking quality. Above 10% inclusion, loss of loaf volume occurs.

## 4. Conclusions

Substitution of WF by FFLF, CLF or DCLF at 5, 10 or 15% leads to a reduced breadmaking potential. The degree of reduction depends on the substituent level.

However, substitution at 5 or 10% by CLF and DCLF gives parameter values at least as good as the control sample and produces an acceptable bread in terms of weight, volume, crumb structure and colour. The FFLF shows a substantial decrease in all values measured. There appears to be a potential market for lupin flour in breadmaking.

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