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Effect of lupin flour incorporation on the physical characteristics of dough and biscuits

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Abstract

Introduction: The incorporation of protein and dietary fibre rich lupin flour to biscuits has the potential to improve the nutritional value however it may adversely affect the physical and sensory properties. *Objectives:* To study the effect of lupin flour incorporation on the physical characteristics and sensory properties of biscuits to provide information to the potential manufacturers. *Methods:* Biscuit samples were prepared by substituting wheat flour with lupin flour at 0–50% levels. The samples were analysed for changes in dimensions, colour, texture and sensory properties. *Results:* Incorporation up to 40% level had no significant effect on biscuit diameter but thickness increased at $\geq$ 20%. No change in the L^* values of dough and biscuits at $\leq$ 20% substitution. The a^* values of dough decreased with increase in lupin flour concentration but in biscuit no significant change was observed up to 20% substitution. The b^* values demonstrated a significant increase at $\leq$ 20% substitution. Biscuit hardness and fracturability demonstrated an increase with the increase in lupin flour concentration at $\geq$ 20%. Sensory evaluation revealed an improvement in colour with lupin flour substitution with no significant changes in taste, flavour, texture and overall acceptability up to 20% substitution. *Conclusion:* Lupin flour can be successfully incorporated into biscuits by replacing up to 20% of wheat flour to increase protein and dietary fibre contents.

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Introduction

Wheat flour-based baked foods such as bread, cakes, muffins and biscuits are commonly consumed popular food items all over the world. Biscuits (cookies in the United States), however, are one of the most common snack foods due to their wide range of types (flexibility to incorporate a range of ingredients), convenience and longer shelf life. The world market for biscuits is projected to reach US$43 billion by the year 2015 and this is primarily driven by the changing consumer trends towards healthy food options and the introduction of new and improved products (Anonymous, 2010).

The major constituent of biscuits is soft wheat flour that is low in protein and dietary fibre contents. Wheat flour proteins are also poor in lysine, an essential amino acid. There has been a trend to improve the nutritional quality of biscuits by adding other sources of protein and dietary fibre such as rice bran and soy concentrate (James *et al.*, 1989), soy protein isolate (Mohsen *et al.*, 2009), sunflower protein isolate (Claughton & Pearce, 1989), bean flour (Dreher & Patek, 1984), oat bran (Lee & Inglett, 2006) and rice bran-fenugreek blends (Sharma & Chauhan, 2002).

The incorporation of lupin flour, which is rich in protein (40%) and dietary fibre (28%), to wheat flour-based products, such as biscuits, has the potential to increase protein and dietary fibre contents. An increased consumption of dietary fibre in daily diet has been recommended by nutritionists to improve health. Major health benefits associated with increased intake of dietary fibres include reduce risk of heart diseases, diabetes, obesity and some forms of cancer (Marlett *et al.*, 2002). Dietary fibres such as various oligosaccharides also have beneficial prebiotic effects on human colon microflora and host metabolism as reviewed by Swennen *et al.* (2006). A combination of lupin and wheat flour can also help improve the amino acid profile of the product. Wheat flour proteins which are poor in lysine and relatively higher in the sulphur-containing amino acids (methionine and cysteine) can be complemented by the amino acids found in lupin protein which is high in lysine and low in sulphur-rich amino acids (Rayas-Duarte *et al.*, 1996; Mann & Truswell, 2002). Lupin flour has a high potential of a 'nonintrusive' ingredient that can be substituted or used as an alternative in foods such as cereal products because lupin flour is pale in colour and low in odour and flavour (Clark & Johnson, 2002). However, texture, flavour and colour changes were resulted directly by the addition of lupin flour in different foods (Jayasena *et al.*, 2009, 2010).

Lupin is lower in cost compared with other similar legumes and protein sources such as soybean (Jayasena & Quail, 2004). Therefore, substitution of lupin flour would improve the nutritional quality of biscuits at a comparatively lower cost. The amount of high protein and high dietary fibre lupin flour that can substitute wheat flour represent a compromise between nutritional improvement and achievement of satisfactory sensory and physical properties of dough and biscuits. Textural properties of biscuit dough are very important in determining the process conditions for biscuit production at commercial level. The objective of the present study was to evaluate the effect of lupin flour incorporation at varying levels on the physical properties of dough and quality and consumer acceptability of biscuits for finding maximum incorporation of lupin flour to improve the nutritional quality without deteriorating the consumer acceptability.

Materials and methods

Raw material

Soft biscuit flour having $< 125\,\mu m$ particle size (Weston Milling, George Weston Foods Ltd., North Ryde, Australia) was purchased from a local supplier. Lupin (*Lupinus angustifolius* L.) flour with $< 125\,\mu m$ particle size was supplied by Coorow Seeds (Coorow, Australia). Flour blends were prepared by mixing lupin flour with soft wheat flour at 0%, 10%, 20%, 30%, 40% and 50% levels. Other ingredients, caster sugar (CSR Limited, Yarraville, Australia), canola oil (Krisco^{TM}, Goodman Fielder, North Ryde, Australia), baking powder (McKenzie's Foods, Altona, Australia) and lecithin were purchased from the local market. Sodium stearoyl lactylate (SSL) (SSL6000, Cognis Deutschland GmbH & Co., Duesseldorf, Germany) was supplied by Cognis (Melbourne, Australia).

Preparation of biscuits

The following recipe was used to prepare biscuits: 500 g flour/flour blend, 170 g sugar, 180 g vegetable oil, 10 g baking powder, 5 g lecithin and 0.2 g SSL. Two types of biscuit formulations were prepared: Formula-A; 100 mL water was added in every recipe regardless of lupin flour incorporation level, Formula-B; incremental amount of water was added corresponding to the lupin flour incorporation level, i.e. 100 mL in control, 110 mL in 10% lupin blend, 120 mL in 20% lupin blend, 130 mL in 30% lupin blend, 140 mL in 40% lupin blend and 150 mL in 50% lupin blend. Both Formula-A and Formula-B were used for dough texture analysis purposes. However, only Formula-B was used for biscuit preparation to get a workable dough for biscuit preparation. Vegetable oil, sugar and lecithin were mixed in a Hobart Mixer (Model N-50G, Hobart Corp., Troy, OH, USA) at medium speed (speed 2) for 2 min, followed by the addition of water and SSL. The mixture was further mixed for 4 min at higher (speed 3) to get a creamy texture. The flour or flour blend premixed with the baking powder were added last and the contents were kneaded to a homogeneous mass. The dough was rolled to a thickness of 5 mm using a roller machine (LaMonferrina P1, Masoero Arturo Co., Asti, Italy) and cut with a 56 mm diameter biscuit cutter. The biscuits were placed on baking trays lined with nongreased baking paper, leaving 25 mm spaces in between, and were baked at 160 °C in a baking oven (Franke Artemis Holding AG, Aarburg, Switzerland) for 22 min. Following baking, the biscuits were cooled at room temperature, packed in polyethylene bags and stored at 23 °C for 1 day before analysis and sensory evaluation.

Moisture and weight

The moisture contents were determined according to AACC (2000) methods. Biscuit weight was determined using a precision scale (HF-2000G, A & D Company Ltd., Tokyo, Japan).

Biscuit dimensions

The diameter (D) and thickness (T) of the biscuits were measured to calculate the spread ratio according to AACC method 10–50D (AACC, 2000). The diameter of the biscuits was measured by placing six biscuits edge-to-edge horizontally and rotating at 90° angle for a duplicate reading. The thickness of biscuits was measured using a digital vernier calliper (Kincrome Australia Pty. Ltd., Scoresby, Australia) by placing six biscuits on top of each other, followed by a duplicate reading recorded by shuffling biscuits. All the measurements were done in three replicates.

Instrumental colour

The Konica Minolta Spectrophotometer (CM = 500i/CM-500C), which uses the CIELAB colour system (L^*, a^* and b^*) was used to measure the surface colour of dough (unbaked biscuits) and baked biscuits. The instrument was equipped with a pulsed xenon arc lamp as a light source, a silicon photodiode array detector and has the illumination/measurement area of $\varnothing$ 11 mm. The instrument was calibrated using the white-coloured disc ($L^* = 98.82$, $a^* = -0.07$ and $b^* = -0.45$) supplied with the instrument before analysis. The surface colour was directly measured by placing the instrument over the top surface of the biscuits. The colour was measured at three different places of each of the three biscuit selected randomly for each treatment. Data were collected for L^* (brightness or whiteness), a^* (redness and greenness) and b^* (yellowness and blueness) values. Colour Difference Index (ΔE^*_{ab}) was calculated from L^*, a^* and b^* colour coordinates by (Anonymous, 1991):

$$\Delta E^*_{ab} = \left[(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2\right]1/2 \quad (1)$$

where as $\Delta L^* = L^*_1 – L^*_2$, $\Delta a^* = a^*_1 – a^*_2$ and $\Delta b^* = b^*_1 - b^*2$.

L^*, a^* and b^* values of control (subscript by 1) and the samples containing lupin flour at varying levels (subscript by 2) were used to develop ΔE^*_{ab} values.

Texture analysis

The texture analyses of dough and biscuits were carried out using a texture analyser (TA.XT2*i*, Stable Micro System Ltd., Godalming, UK). The parameters used for texture profile analysis of dough were as follows: 25 kg load cell, plunger diameter 60 mm, constant cross-head speed 1.0 mm s^{-1} diameter, compression 40% of the original thickness for two times, recovery period between the two strokes 5 s. Biscuit dough (rested at 23 °C) was sheeted to 1 cm thickness using a roller pin and cut into 50 mm diameter discs with a circular shape cutter. Based on the force–time curve hardness (the peak force of the first compression), cohesiveness (the ratio of the areas of the two compression peaks; A_2/A_1), springiness (the height of the dough disc during the time elapsed between the end of the first bite and start of the second bite) and adhesiveness (the negative force area for the first bite) (Bourne, 1978).

For texture analysis of the biscuits the snap test was carried out with the texture analyser using a three-point bend rig (HDP-90/3BP) and 25 kg load cell. The parallel biscuit supports were placed 40 mm apart. The test was performed with pretest speed of 1.0 mm s^{-1}, test speed 3.0 mm s^{-1} and posttest speed 10.0 mm s^{-1}. The maximum snap force and the distance were calculated for six replicates of each treatment to determine biscuit hardness and fracturability, respectively (Anonymous, 2000).

Sensory evaluation

The sensory evaluation of biscuit samples was carried out to determine the acceptability of lupin incorporated biscuits. Ten semitrained panellists were selected. The panellists were provided with six biscuit samples prepared from flour blends containing 0%, 10%, 20%, 30%, 40% and 50% lupin flour. Biscuits were prepared a day ahead of sensory evaluation and stored at room temperature after packing in zip-locked polyethylene bags. On the day of evaluation, biscuits were placed in small plates and labelled with three-digit random codes. Panellists were provided with distilled water and unsalted crackers to cleanse their palates between samples. The biscuit samples were presented in random order and panellists were asked to rate their assessment of colour, taste, flavour, crispiness and overall acceptability on a nine-point hedonic scale (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much and 9 = like extremely).

Statistical analysis

The data collected for physical measurements and sensory properties were analysed by applying SPSS 17 and the means were compared using Tukey's HSD test at $P \leq 0.05$. Correlation coefficient between variable were calculated using Pearson's correlation.

Results and discussion

Proximate composition

Proximate analysis was not carried out except for moisture contents as it could be possible to estimate changes in protein and dietary fibre contents (main nutritional changes) from the compositions of wheat flour and lupin flour. It was obvious that replacement of soft wheat flour, containing 8.0% protein and 3.2% dietary fibre (data supplied by the manufacturer) with lupin flour containing 42.1% protein and 29.1% dietary fibre (data supplied by the manufacturer) would result in a significant increase in protein and dietary fibre contents of biscuits. However our main focus was to study the effect of adding protein and dietary fibre rich lupin flour on the physical and sensory properties of dough and biscuits.

Moisture contents were higher in biscuit samples containing lupin flour as compared with the control (Table 1). It may be due to the higher initial moisture contents of biscuits before baking. Extra water was added in the biscuits dough containing lupin flour to make it pliable for biscuit formation. It may also be due to the increase in protein and diary fibre contents of the biscuits by the incorporation of lupin flour. Increase in the protein content due to substitution of soy protein isolate at 5–20% level or chickpea flour and broad bean flour caused a significant increase in the moisture contents of cookies (Taha *et al*., 2006; Mohsen *et al*., 2009). This could be due to the increase in hydrophilic sites available that compete for the limited free water in biscuit dough (Kissell & Yamazaki, 1975).

Biscuit dimensions

Baking generally causes a substantial increase in the diameter of biscuits due to CO_2 gas production by leavening agents and rapid water evaporation. Biscuits expand both in height and width in the early stage but collapse at the later stage of the baking process. This collapse is apparently due to structural properties of gluten in cookie flour for the two-dimensional collapsible film formation rather than three-dimensional elastic network formation (Slade & Levine, 1994). The replacement of soft wheat flour with lupin flour up to 40% level had no significant effect on the biscuit diameter (Table 1). Replacement at 50%, however, caused a significant decrease in the biscuit diameter. The reduction in biscuit diameter due to the addition of different types of starches and fibres such as pectin, rice bran, oat bran and inulin has been reported in previous studies (James *et al*., 1989; Zoulias *et al*., 2002; Lee & Inglett, 2006). It was probably caused by the formation of an elastic network formation that causes shrinkage after baking. Addition of lupin flour, which is high in dietary fibre (29.1%) could act in the similar way to reduce the diameter of the biscuits.

Biscuit quality is generally associated with soft wheat flour of low-protein content (Morris & Rose, 1996). Addition of high protein flours/sources causes a negative impact on the cookie spread. The defatted soy flour and soy protein isolates drastically reduced cookie width (Tsen *et al*., 1973). Cookies spread was reduced by the soy-derived protein concentrates in sugar snap cookies at differential rate depending upon concentration and functionality of proteins (Kissell & Yamazaki, 1975). Cookies prepared by incorporating soy concentrate or soy isolate demonstrated less spread (even with added shortening, water and emulsifier) than the wheat flour cookies (James *et al*., 1989). In contrast to these studies addition of high protein (40%) lupin flour did not affect on the biscuit diameter up to 40% replacement level.

With no effect on the biscuit diameter, an increase in the biscuit height (thickness) was found with the increase in lupin flour concentration (Table 1). Biscuits prepared by replacing soft wheat flour with lupin flour at $\geq$20% demonstrated a significant increase ($P \leq 0.05$) in thickness. Biscuit prepared by 20%, 30%, 40% and 50% replacement of wheat flour with lupin flour were 5%, 12%, 14% and 16% thicker than the control, respectively. The results are in agreement to those of other researchers showing an increase in biscuit thickness when high protein sources were added into the formulation (Tsen *et al*., 1973). Increase in the biscuit thickness resulted in a corresponding decrease in spread ratio but at $\geq$30% lupin flour incorporation level. Samples prepared using flour blends containing up to 20% lupin flour demonstrated no difference in spread ratio as compared with the control sample. Biscuits fortified with protein rich sources such as isolated soy protein, chickpea flour, broad bean flour or black gram flour showed a decrease in the spread factor with the increase in the level of fortification (Sharma & Chauhan, 2002; Taha *et al*., 2006).

Table 1 Effect of lupin flour substitution on the physical properties of biscuits

Lupin flour substitution (%)	Moisture ($g/100\,g^{-1}$)	Dry weight ($g\,U^{-1}$)	Diameter (mm)	Height (mm)	Spread ratio ($diameter/height^{-1}$)
0 (control)	1.36 ± 0.05^{a}	15.3 ± 0.4^{a}	59.7 ± 0.9^{a}	8.92 ± 0.20^{d}	6.7 ± 0.1^{a}
10	2.45 ± 0.17^{b}	14.7 ± 0.6^{ab}	59.4 ± 0.6^{ab}	8.97 ± 0.05^{d}	6.6 ± 0.6^{a}
20	3.30 ± 0.20^{c}	14.5 ± 0.5^{ab}	58.9 ± 0.6^{ab}	9.33 ± 0.10^{c}	6.3 ± 0.2^{ab}
30	3.78 ± 0.20^{c}	14.6 ± 0.3^{ab}	58.9 ± 0.9^{ab}	9.97 ± 0.05^{b}	5.7 ± 0.2^{b}
40	3.24 ± 0.21^{c}	14.9 ± 0.7^{ab}	58.7 ± 1.0^{ab}	10.20 ± 0.05^{a}	5.8 ± 0.6^{b}
50	3.33 ± 0.38^{c}	14.0 ± 0.9^{b}	58.3 ± 0.9^{b}	10.36 ± 0.05^{a}	5.6 ± 0.2^{b}

Results are expressed as means $\pm$ SD, $n = 3$.
Means with different superscripts within a column are significantly different ($P \leq 0.05$).

Instrumental colour

Lupin flour is naturally yellower than wheat flour owing to its high carotenoids contents (Mohamed & Rayas-Duarte, 1995; Wang *et al.*, 2008). Replacement of wheat flour with lupin flour in the formulation affected both dough and biscuit colours at $\geq 30\%$ substitution levels. The L^* value that represent lightness showed no significant change up to 20% lupin flour substitution both in dough and biscuits (Table 2). At $\geq 30\%$ substitution levels there was a decrease in lightness because of the loss of the characteristic white colour of the wheat flour. The changes in L^* value of dough and biscuit demonstrated high correlation ($r = -0.82$ and0.88, respectively) with increase in lupin flour concentration.

The a^* value (greenness or redness) for dough demonstrated a consistent increase ($r = 0.99$) with increase in the lupin flour concentration but in case of biscuit the increase was found only at $\geq 30\%$ substitution levels ($r = 0.88$). However, the b^* values (yellowness) constantly increased, both for dough and biscuits, with increase in the lupin flour concentration in the formulation (Table 2) demonstrating a correlation coefficient (r) of 0.78 and 0.85, respectively.

The results coincide with previous results reported for biscuits and cookies made by incorporating high protein soy and other legume flours. Cookies prepared by incorporating rice bran and soy concentrate or soy protein isolate were darker in colour than the wheat flour cookies (James *et al.*, 1989; Mohsen *et al.*, 2009). The L^* value of biscuits decreased and b^* value increased when wheat flour was replaced with broad bean flour at 12% level (Taha *et al.*, 2006).

The ΔE^*_{ab} values that reflect total colour difference from the control sample showed an increase with the increase in lupin flour substitution both in dough and biscuit samples. However, dough had higher colour differences than the biscuits. In case of biscuits the change in colour was masked by the development of a light-brown colour during baking process which develops mainly due to increase in reaction of reducing sugars with amino acids, i.e. the Maillard reaction (Claughton & Pearce, 1989).

Textural properties

Textural properties of dough

Biscuit dough is a complex dough in terms of its rheological properties and determination of its textural properties provides valuable information on handling and processing procedures especially the machining requirements. Biscuit dough samples prepared by adding the same amount of water demonstrated a substantial effect on the textural properties due to the lupin flour incorporation (Table 3). All of the textural properties, except for cohesiveness, demonstrated significant changes due to incorporation of lupin flour in the formulation. The dough hardness increased with the increase in lupin flour incorporation, i.e. 26.7*N* for control to 65.8*N* for 50% lupin flour incorporated dough. Both springiness and adhesiveness of the dough decreased with the increase in lupin flour incorporation. This may be due to higher protein or lower starch contents or even difference in the type of polysaccharide of lupin flour than the wheat flour that affect the texture of the dough. The presence of high molecular weight polysaccharide affect the water absorbing capacity of the cookie dough during mixing and thus effect the rheological properties of the dough (Faridi, 1990).

Cohesiveness, however, remained constant with the increase in lupin flour incorporation. Cohesiveness is a ratio that is obtained by dividing the energy consumed during the second compression (A_2) by the energy consumed during the first compression (A_1). Lower value of cohesiveness for one sample than the other generally indicates that less energy is required during the first compression. However, this may not be the case when both A_1 and A_2 are increasing or decreasing with each other. Similar was the case with our samples. Both A_1 and A_2 values were increasing with the

Table 2 Effect of lupin flour substitution on instrumental colour of dough (unbaked biscuits) and biscuits

Lupin flour substitution (%)	Dough colour				Biscuit colour			
	L^*	a^*	b^*	ΔE^*_{ab}	L^*	a^*	b^*	ΔE^*_{ab}
0 (control)	66.8 ± 1.2^a	-0.8 ± 0.1^f	23.2 ± 1.0^d	0.0 ± 0.0^e	75.6 ± 1.9^a	1.7 ± 0.5^c	30.6 ± 1.9^d	0.0 ± 0.0^e
10	64.9 ± 1.5^a	-0.3 ± 0.2^e	43.0 ± 0.8^c	19.9 ± 0.7^d	77.5 ± 1.8^a	1.6 ± 0.4^c	39.9 ± 0.7^c	9.5 ± 0.6^d
20	64.9 ± 2.5^a	2.4 ± 0.5^d	50.2 ± 1.7^b	27.3 ± 1.4^c	76.0 ± 1.7^a	2.3 ± 0.4^c	44.1 ± 0.5^b	13.5 ± 0.5^c
30	62.4 ± 1.9^b	4.6 ± 0.3^c	52.2 ± 1.7^a	29.8 ± 1.4^{bc}	73.6 ± 1.4^b	4.2 ± 1.3^b	46.5 ± 0.9^a	16.1 ± 1.0^b
40	58.2 ± 1.2^c	6.2 ± 0.2^b	53.3 ± 2.0^a	28.2 ± 1.4^{ab}	70.7 ± 0.8^c	6.9 ± 0.4^a	47.4 ± 0.7^a	17.9 ± 0.5^a
50	59.4 ± 1.2^c	7.9 ± 0.4^a	52.3 ± 1.7^a	31.2 ± 1.3^a	68.3 ± 0.3^d	7.9 ± 0.4^a	46.2 ± 0.5^a	17.9 ± 0.5^a

Results are expressed as means ± SD, $n = 6$.
Means with different superscripts within a column are significantly different ($P \leq 0.05$).

Table 3 Effect of lupin flour substitution on the textural properties of biscuit dough

Lupin flour substitution (%)	Hardness (*N*)		Cohesiveness (*N*, mm^{-1})		Springiness (mm)		Adhesiveness (*N*)	
	A	B	A	B	A	B	A	B
0 (control)	26.7 ± 2.3^{d}	26.7 ± 2.3^{a}	0.32 ± 0.05^{a}	0.32 ± 0.05^{a}	2.41 ± 0.35^{a}	2.41 ± 0.35^{a}	7.50 ± 1.43^{a}	7.50 ± 1.43^{a}
10	30.0 ± 1.1^{d}	25.2 ± 0.7^{ab}	0.27 ± 0.02^{ab}	0.30 ± 0.03^{a}	1.88 ± 0.10^{bc}	2.12 ± 0.17^{a}	5.07 ± 0.55^{b}	5.33 ± 1.59^{a}
20	35.5 ± 1.8^{c}	20.0 ± 0.3^{c}	0.26 ± 0.01^{b}	0.33 ± 0.02^{a}	1.69 ± 0.05^{c}	2.11 ± 0.21^{a}	4.56 ± 0.31^{b}	5.45 ± 0.79^{a}
30	40.0 ± 2.6^{c}	22.6 ± 0.8^{bc}	0.27 ± 0.01^{ab}	0.32 ± 0.03^{a}	1.77 ± 0.06^{bc}	2.01 ± 0.13^{a}	4.67 ± 0.30^{b}	6.00 ± 1.30^{a}
40	53.4 ± 1.1^{b}	23.3 ± 1.6^{b}	0.29 ± 0.01^{ab}	0.34 ± 0.04^{a}	1.92 ± 0.02^{b}c	2.07 ± 0.20^{a}	4.69 ± 0.46^{b}	7.10 ± 1.73^{a}
50	65.8 ± 4.0^{a}	27.5 ± 1.5^{a}	0.32 ± 0.01^{a}	0.35 ± 0.01^{a}	2.08 ± 0.06^{b}	2.10 ± 0.09^{a}	4.85 ± 0.27^{b}	7.10 ± 0.84^{a}

Results are expressed as means ± SD, $n = 3$.
Means with different superscripts within a column are significantly different ($P \leq 0.05$).
A, dough samples prepared by using Formula-A; B, dough samples prepared by using Formula-B.

increase in lupin flour incorporation in the recipe resulting in almost constant cohesiveness values.

Addition of additional water corresponding to the lupin flour concentration in the biscuit formulation, however, removed the effect of lupin flour incorporation on the dough textural properties. Dough samples prepared with additional water showed no significant changes due to lupin flour incorporation in cohesiveness, springiness and adhesiveness values (Table 3). Dough hardness, however, was less than the control in some samples. The results revealed that textural properties of lupin flour incorporated dough can be controlled by manipulating the amount of water in the formulation.

Textural properties of biscuits

Significant changes in the textural properties of biscuits were found due to the incorporation of lupin flour. Both hardness and fracturability increased with the increase in lupin flour incorporation (Table 4). The increase in hardness and fracturability may be due to increase in thickness (height) of the biscuits (Table 1), which gives physical strength to the biscuit structure. The biscuit hardness demonstrated a high correlation ($r = -0.94$) with increase in lupin flour concentration. The other reason may be the substantial increase in protein and dietary fibre contents that affect on the texture properties of biscuits. Polydextrose, classified as dietary fibre, when added to the wheat cookies increased hardness and brittleness significantly (Zoulias *et al*., 2002). Defatted maize germ containing 27.6% protein and 13.1% dietary fibre caused a significant increase in cookie hardness (breaking strength) when added at above 15% levels (Nasir *et al*., 2010). Similarly, biscuit hardness significantly increased when wheat bran, oat bran or barley bran was added at ≥10% levels (Sudha *et al*., 2007). Addition of high protein and high fibre mixtures of soy protein isolate and various types of brans resulted in significant increase in hardness and chewiness (James *et al*., 1989).

Table 4 Textural properties of biscuits as affected by lupin flour substitution

Lupin flour substitution (%)	Hardness (*N*)	Fracturability (mm)
0 (control)	14.2 ± 1.8^{d}	0.26 ± 0.02^{d}
10	21.4 ± 1.6^{d}	0.51 ± 0.04^{c}
20	33.3 ± 4.3^{c}	0.57 ± 0.07^{bc}
30	42.5 ± 2.7^{bc}	0.72 ± 0.04^{ab}
40	52.7 ± 4.9^{ab}	0.83 ± 0.02^{a}
50	62.8 ± 6.7^{a}	0.84 ± 0.09^{a}

Results are expressed as means ± SD, $n = 6$.
Means with different superscripts within a column are significantly different ($P \leq 0.05$).

Sensory evaluation

The sensory evaluation results for colour, taste, flavour, crispiness and overall acceptability of the biscuit samples are presented in Table 5. Addition of lupin flour exhibited a substantial effect on the sensory properties of biscuits. The sensory scores for colour (consumer likeness of colour) of biscuits were improved by the incorporation of lupin flour. A light yellow colour imparted by natural yellow pigments present in lupin flour was attractive to the judges (up to 50% lupin substitution) as compared with the whitish colour of the control sample. Yellowness also increased with the increase in lupin substitution as tested by instrumental method (increase in b^* value; Table 2). Similar improvements in colour of different foods by lupin incorporation have been reported in other studies. Colour scores of spaghetti containing 15–30% lupin flour were much higher than those prepared by adding 15–30% light buck wheat or amaranth (Rayas-Duarte *et al*., 1996). Instant noodle samples containing up to 30% lupin

Table 5 Effect of lupin flour substitution on the sensory properties of biscuits

Lupin flour substitution (%)	Colour	Taste	Flavour	Crispiness	Overall acceptability
0 (control)	5.2 ± 0.9^{b}	7.2 ± 1.5^{a}	6.8 ± 1.3^{a}	7.6 ± 2.4^{a}	6.9 ± 2.4^{a}
10	6.5 ± 1.1^{a}	6.7 ± 1.3^{ab}	6.5 ± 1.1^{ab}	7.3 ± 0.8^{a}	6.5 ± 1.1^{a}
20	6.6 ± 1.2^{a}	6.1 ± 2.1^{abc}	6.1 ± 1.2^{abc}	7.1 ± 1.1^{ab}	6.0 ± 1.8^{ab}
30	6.7 ± 0.8^{a}	5.1 ± 1.5^{bc}	5.5 ± 1.9^{bcd}	6.1 ± 1.3^{bc}	5.8 ± 1.4^{abc}
40	7.0 ± 1.7^{a}	5.0 ± 1.2^{c}	5.3 ± 1.3^{cd}	5.6 ± 2.1^{c}	5.1 ± 1.2^{bc}
50	7.4 ± 1.9^{a}	5.0 ± 1.7^{c}	4.8 ± 1.9^{d}	5.3 ± 1.8^{c}	4.8 ± 1.7^{c}

Results are expressed as means ± SD, $n = 10$.
Means with different superscripts within a column are significantly different ($P \leq 0.05$).

flour had higher colour scores than those prepared solely with wheat flour (Jayasena *et al*., 2008).

Taste and flavour scores of the biscuit samples were not affected by the lupin substitution up to 20% level. However, at ≥30% lupin substitution level the mean taste and flavour scores decreased significantly (Table 5). It might be due to the beany flavour associated with lupin flour. Taste and flavour of some other products was also affected by lupin flour addition at higher levels (> 30% levels) mainly due to a beany flavour and/or an aftertaste (Hall & Johnson, 2004; Jayasena *et al*., 2008).

Similarly, up to 20% substitution of wheat flour with lupin flour did not affect crispiness of biscuits (Table 5). At ≥30% levels, however, the crispiness scores were significantly lower than that of control. This may be due to texture hardness caused by high protein and dietary fibre contents of lupin flour when added at higher levels. Dietary fibres sourced from apple, lemon and wheat, when added at ≥15% levels caused a reduction in sensory scores for texture of cookies (Uysal *et al*., 2007).

Overall acceptability scores provide a general acceptability of the product based on all of the sensory parameters. The biscuit samples prepared by replacing wheat flour with up to 30% lupin flour had no significant difference from the control sample. At ≥40% replacement level, however, a significant decrease ($P \leq 0.05$) in the overall acceptability score was observed.

The sensory data revealed that replacement of wheat flour with lupin flour up to 20% level cause no negative effect on the sensory quality of biscuits. It rather improved the sensory quality of the biscuits by improving the colour. Compared with other similar high dietary fibre flours lupin flour is more versatile to be added into biscuits. Lupin flour can also be added into a range of other products at variable levels (depending upon the type of product) such as bread, pasta, instant noodles, cookies, tofu and tempe (Hall & Johnson, 2004; Jayasena *et al*., 2007, 2008, 2010).

In a previous study Hegazy and Faheid (1990) reported that texture scores were decreased but colour and taste scores improved with increase in the lupin flour concentration in the cookies. Their results indicated that lupin flour could replace at least 15% of the wheat flour in cookie formula without adversely affecting baking performance, physical characteristics and acceptability. They used *Lupinus termis* flour after debittering process. However, this study reveals that lupin flour (*L. angustifolius*) can replace up to 20% of soft wheat flour in plain biscuit formulation without adversely affecting its physical and sensory properties.

Conclusions

High protein and high dietary fibre lupin flour can be successfully incorporated into biscuits by replacing up to 20% of wheat flour. By replacing wheat flour with lupin flour at 20% level substantial improvement in the protein and fibre contents can be achieved without adversely affecting physical and sensory properties of biscuits. Addition of lupin rather improves the sensory characteristic of colour making biscuits more attractive to the consumers. Replacement of lupin flour up to 30% levels may be acceptable to the health conscious consumers who would be willing to compromise with change in taste and flavour. As compared with other natural protein and dietary fibre sources lupin flour is lower in cost. Therefore, substitution of sweet lupin flour would improve the nutritional value and quality of biscuits at comparatively lower cost.

References

AACC. (2000). *Approved Methods of the American Association of Cereal Chemists*. American Association of Cereal Chemists, Minnesota.

Anonymous. (1991). *Chroma Meter (CR-300/CR-310/CR-321/CR-331/CR-331C), Instruction Manual*. Minolta Co. Ltd, Tokyo.

Anonymous. (2000). *Texture Expert Exceed 2.64 – Application Guide-Bakery*. Stable Micro System Ltd, Surrey, UK.

Anonymous. (2010) Global food market trends. *Food Australia*, **62**, 301–302.

Bourne M.C. (1978) Texture profile analysis. *Food Technology*, **32**, 62–66, 67.

Clark R., Johnson S. (2002) Sensory acceptability of foods with added lupin (*Lupinus angustifolius*) kernel fiber using pre-set criteria. *Journal of Food Science*, **67**, 356–362.

Claughton S.M., Pearce R.J. (1989) Protein enrichment of sugar-snap cookies with sunflower protein isolates. *Journal of Food Science*, **54**, 354–356.

Dreher M.L., Patek J.M. (1984) Effects of supplementation of shortbread cookies with roasted whole bean flour and high protein flour. *Journal of Food Science*, **49**, 922–924.

Faridi H. (1990) Application of rheology in the cookie and cracker industry. In: *Dough Rheology and Baked Product Texture* eds Faridi H., Faubion J.M. pp. 372, Chapman & Hall Inc., New York.

Hall R.S., Johnson S.K. (2004) Sensory acceptability of foods containing Australian sweet lupin (*Lupinus angustifolius*) flour. *Journal of Food Science*, **69**, SNQ92–SNQ97.

Hegazy N.A., Faheid S.N. (1990) Rheological and sensory characteristics of doughs and cookies based on wheat, soybean, chick pea and lupine flour. *Die Nahrung*, **34**, 835–841.

James C., Courtney D.L.D., Lorenz K. (1989) Rice bran-soy blends as protein supplements in cookies. *International Journal of Food Science and Technology*, **24**, 495–502.

Jayasena V., Kardono L., Quail K., Coorey R. (2007) Manufacturing of lupin tempe. In: *Agribusiness Crop Updates* ed Parker W. pp. 61–62, Department of Agriculture and Food, Perth, WA.

Jayasena V., Khu W.S., Nasar-Abbas S.M. (2010) The development and sensory acceptability of lupin-based tofu. *Journal of Food Quality*, **33**, 85–97.

Jayasena V., Leung P., Nasar-Abbas S.M. (2008) Development and quality evaluation of lupin-fortified instant noodles. In: *Proceedings of 12th International Lupin Conference* eds Palata J.A., Berger J.D. pp. 473–477, International Lupin Association, Fremantle, WA.

Jayasena V., Nasar-Abbas S.M., Yii Y.J., Senaratna M. (2009) Development of lupin based low cost, high fibre and high protein innovative foods. In: *Proceedings of the International Conference on Innovations in Food Processing Technology and Engineering (ICFPTE'08), 19–20 January, Thailand*. pp. 1–10, Asian Institute of Technology, Pathumthani, Thailand.

Jayasena V., Quail K. (2004) Lupin: a legume with a future. *Food and Beverage Asia*, **12**, 16–21.

Kissell L.T., Yamazaki W.T. (1975) Protein enrichment of cookie flours with wheat gluten and soy flour derivatives. *Cereal Chemistry*, **52**, 628–649.

Lee S., Inglett G.E. (2006) Rheological and physical evaluation of jet-cooked oat bran in low calorie cookies. *International Journal of Food Science and Technology*, **41**, 553–559.

Mann J., Truswell A. (2002). *Essential of Human Nutrition*. Oxford University Press, New York.

Marlett J.A., McBurney M.I., Slavin J.L. (2002) Position of the American dietetic association: Health implications of dietary fiber. *Journal of the American Dietetic Association*, **102**, 993–1000.

Mohamed A.A., Rayas-Duarte (1995) Composition of *Lupinus albus*. *Cereal Chemistry*, **72**, 643–647.

Mohsen S.M., Fadel H.H.M., Bekhit M.A., Edris A.E., Ahmed M.Y.S. (2009) Effect of substitution of soy protein isolate on aroma volatiles, chemical composition and sensory quality of wheat cookies. *International Journal of Food Science and Technology*, **44**, 1705–1712.

Morris C.F., Rose S.P. (1996) Wheat. In: *Cereal Grain Quality* eds Henry R.J., Kettwell P S. pp. 3–54, Chapman & Hall, London.

Nasir M., Siddiq M., Ravi R., Harte J.B., Dolan K.D., Butt M.S. (2010) Physical quality characteristics and sensory evaluation of cookies made with added defatted maize germ flour. *Journal of Food Quality*, **33**, 72–84.

Rayas-Duarte P., Mock C.M., Satterlee L.D. (1996) Quality of spaghetti containing buckwheat, amaranth, and lupin flours. *Cereal Chemistry*, **73**, 381–387.

Sharma H.R., Chauhan G.S. (2002) Effect of stabilised rice bran-fenugreek blends on the quality of breads and cookies. *Journal of Food Science and Technology*, **39**, 225–233.

Slade L., Levine H. (1994) Structure-function relationships of cookie and cracker ingredients. In: *The Science of Cookie and Cracker Production* ed Faridi H. pp. 54–64, Chapman & Hall, New York.

Sudha M.L., Vetrimani R., Leelavathi K. (2007) Influence of fibre from different cereals on the rheological characteristics of wheat flour dough and on biscuit quality. *Food Chemistry*, **100**, 1365–1370.

Swennen K., Courtin C., Delcour J. (2006) Non-digestible oligosaccharides with prebiotic properties. *Critical Reviews in Food Science and Nutrition*, **46**, 459–471.

Taha M.R., Majdi A.A., Khalil I.E. (2006) Effect of chickpea, broad bean, or isolated soy protein additions on the physicochemical and sensory properties of biscuits. *Journal of Food Science*, **71**, S438–S442.

Tsen C.C., Peters E.M., Schaffer T., Hoover W.J. (1973) High protein cookies. I. Effect of soy fortification and surfactant. *Bakers Digest*, **47**, 34–39.

Uysal H., Bilgicli N., Elgun A., Ibanoglu S., Herken E.N., Demir K. (2007) Effect of dietary fibre and xylanase enzyme addition on the selected properties of wire-cut cookies. *Journal of Food Engineering*, **78**, 1074–1078.

Wang S.F., Errington S., Sweetingham M., Yap H.H., Smith L. (2008) Studies on carotenoids from lupin seeds. In: *Proceedings of 12th International Lupin Conference* eds Palata J.A., Berger J.D. pp. 198–202, International Lupin Association, Fremantle, WA.

Zoulias E.I., Oreopoulou V., Kounalaki E. (2002) Effect of fat and sugar replacement on cookie properties. *Journal of the Science of Food and Agriculture*, **82**, 1637–1644.

