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Effect of storage time on the antinutritional factors, stability and rheological behaviours of flaxseed fortified wheat flours

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RESEARCH ARTICLE

Abstract

Whole wheat flour (WWF) and straight grade flour (SGF) were fortified with partially defatted flaxseed flour (PDF) and full fat flaxseed flour (FFF). The fortified flours were stored for a period of 60 days. Studies were conducted to evaluate the influence of storage intervals on stability, cyanogenic glycoside (HCN) content and rheological properties at 0, 30 and 60 days of storage. No HCN was detected in WWF samples while, its maximum concentration 0.37 and 0.44 mg/kg was found in 20% PDF and FFF fortified WWF, respectively. The storage intervals showed non-significant effect on the concentration of HCN among different composite flours. The peroxide value ranged from 0.82 to 0.92 mEq/kg in PDF fortified SGF composite flours, while it varied from 0.82 to 1.01 mEq/kg in FFF fortified SGF composite flours. The mixing time decreased significantly as the level of PDF and FFF fortification increased in SGF. Lower mixing times were recorded in both types of composite flours after 60 days of storage interval while fresh samples exhibited the higher mixing times. Significant changes in peak height percentages of both types of flours were observed during storage period of 60 days.

Keywords: cyanogenic glycosidee, flaxseed, mixing time, peak height percentage, peroxide value, storage

1. Introduction

The food based approaches namely food fortification and dietary improvement appeared to be the most sustainable, potentially long lasting strategic measures against micronutrient malnutrition (Hurrell, 1997). The technology of composite flour refers to the process of amalgamation of wheat flour with the flours of other edible plant materials. It makes the use of local and potentially health beneficial raw materials for the production of high quality, healthy and economical food products for the masses. Now a day's interest has led to produce a wide variety of foods referred to as functional foods and nutraceuticals because these type of foods offer either therapeutic or preventive medicinal health benefits in addition to provision of their basic nutrition. Addis and Warner (1991) found that in higher oil containing functional foods, lipid per oxidation results in the deterioration of their nutritive value and stability. The flavour and taste of such foods or the foods in which these foods are added are also affected (Barlow, 1990). The oxidative rancidity is a major cause of development of bad odour and flavour in the foods containing higher oil contents. Free radical formation is responsible for that process. The by-product of rancidity process is the development of peroxides. The measurement of peroxide value (POV) helps to determine the level of amount of rancidity present (Martin, 2004). The flaxseed meal or oil can easily be incorporated into common food products such as breads, rolls, cereals, muffins, margarines, and salad dressings (Fitzpatrick, 2006). The mechanical and rheological properties of the dough exert promising effect on the overall quality of baked products (Blokshma and Bushuk, 1988). Nature of ingredients, their proportions, mixing time and beating conditions are responsible for the quality of batter which finally determines the baked product quality (Baixauli *et al.*, 2007). The dough rheological properties are influenced by the structure of the aggregates and their tendency to interact with each other. Quality and quantity of the proteins affect the water absorption capacity of the dough (Finney, 1984). The ash, fat, crude protein and crude fibre full fat flaxseed flour (FFF) supplemented whole wheat flour (WWF) was higher as compared to plain flour, moreover the health potentials of flaxseed are also proved in previous studies of Hussain *et al.* (2006, 2012, 2013). Keeping in view all the studied benefits of flaxseed, the objective of present study is to explore the storage stability and changes in the rheological behaviour of flaxseed fortified wheat flour during storage. The influence of storage period on antinutritional factors of the composite flour was also studied.

2. Materials and methods

Raw materials

Two types of food grains were used in the study. The wheat flour was used as a base material for the preparation of composite flours fortified with flaxseed. The wheat variety SH 2002 was purchased from Wheat Research Institute (Faisalabad, Pakistan) and Chandni variety of flaxseed was purchased from Oil Seeds Research Institute (Faisalabad, Pakistan).

Primary treatment of raw materials

The cleaning of flaxseed and wheat grains was performed manually to remove damaged seeds, dust particles, seeds of other grains/crops and other impurities such as metals and weeds. The flaxseed grains were roasted in the household microwave oven for 2.5 minutes with 480 W output under the operating frequency of 2,450 MHz by following the method described by Yang *et al.* (2004). Flaxseed subjected to roasting through microwave processing was divided into two parts. Half of the roasted flaxseed grains were partially defatted by using the screw type mechanical press.

Preparation of flours

Whole wheat flour

The WWF for chapattis was prepared by milling the wheat grains through pin mill locally known as China 'chakki' (grinder).

Straight grade flour

The wheat grains were tempered to 15.5% moisture level and allowed to stand for 24 hours at room temperature in a closed container in order to equilibrate moisture content in grains. The water required to temper the wheat grains was computed according to the expression given in Equation 1 (AACC, 2000):

Weight of water to be added =

$$\frac{100 - \text{original moisture}}{100 - \text{desired moisture}} - 1 \times \text{weight of wheat sample} \qquad (1)$$

The tempered wheat grains were milled in a Quardrumate Senior Mill (Brabender® GmbH & Co. KG, Duisburg, Germany) to get straight grade flour (SGF) by blending reduction and break roll flour mill streams. The milling of wheat grain samples was carried out by following the instructions provided in AACC (2000).

Flaxseed flour

The full fat flaxseed grains and partially defatted flaxseed meal were milled by passing through a pin mill locally known as China 'chakki' (grinder; Hosokawa Alpine, Augsburg, Germany).

Preparation and storage of composite flours

All types of flours were passed through a 60 mesh sieve. The composite flour were prepared by blending the WWF and SGF with varying levels of partially defatted and full fat flaxseed flours (4, 8, 12, 16 and 20%). All types of composite flours were stored in tin cans for 60 days at room temperature (22±2 °C) to study the variation in quality during storage.

Estimation of cyanogenic glycoside

Cyanogenic contents in the composite flour were determined after 0, 30 and 60 days of storage intervals according to the method given in AOAC (1990). The estimation of cyanogenic glycoside (HCN) contents of composite flours was performed by taking 20 g sample in a Kjeldhal flask (Donghai Country AOBO Quartz Products Co. Ltd, Jiangsu, China). The flask was given rest for two hours after adding 200 ml water into it. After rest, distillation was carried out and distillate was collected in a flask containing 20 ml of 2.5% NaOH solution until distilled to a definite volume. 8 ml of 6 M NH_4OH and 2 ml of 5% potassium iodide solution were added to the distillate. Then the whole contents were titrated against 0.02 M $AgNO_3$ solution. HCN contents of sample were calculated according to Equation 2:

$$\text{HCN (mg)} = \text{ml of 0.02 M } AgNO_3 \text{ solution used} \times 1.08 \qquad (2)$$

Peroxide value

The peroxide value of different composite flours was determined after 0, 30 and 60 days of storage intervals according to the method described by Kirk and Sawyer (1991).

Mixographic studies

The rheological behaviour of different flour blends was studied by running the samples through Mixograph (National Mfg. Co., Lincoln, NE, USA) after 0 and 60 days of storage intervals according to the methods given in AACC (2000) method no. 54-40A. The mixograph equipped with 10 g bowl capacity was used to determine dough development time and peak height percentage. The dough development time from mixograms was observed as the time from the start of the mixogram to the time where the centre of the curve attained maximum height while the peak height percentage described as a height of mixogram at optimum development and was recorded as percentage of height.

Statistical analysis

The data obtained for each parameter were subjected to statistical analyses using Minitab statistical package (Minitab Quality Companion 2003; Softonic International S.A., Barcelona, Spain). The level of significance ($P\leq0.05$) at 0.05 alpha was determined by applying analysis of variance technique (one factor and two factor factorial completely randomized design). Significant ranges were further postulated using Duncan's multiple range mean comparison test (Steel *et al.*, 1997).

3. Results and discussion

Cyanogenic glycosides contents of composite flours

The HCN content of different composite flours presented in Table 1 indicated that addition of defatted flaxseed flour (PDF) or FFF in WWF or SGF resulted in significant increase in HCN content in all composite samples. The non-roasted FFF contained 145.72±5.21 mg/kg of HCN (Hussain *et al.*, 2008). No HCN was detected in WWF samples while, its maximum concentration 0.37 and 0.44 mg/kg was found in 20% PDF and FFF fortified WWF, respectively. There was a similar increasing trend of HCN concentration in SGF composite flours fortified with FFF and PDF. It is also evident in Table 1 that the highest HCN content (0.39 mg/kg) was found in 20% PDF fortified SGF composite flour. The SGF composite flour fortified with 20% FFF also possessed significantly the highest content of HCN (0.44 mg/kg) followed by SGF fortified with 16% FFF (0.36 mg/kg). The storage intervals showed non-significant effect on the concentration of HCN among different composite flours. It is evident from the Table 1 that HCN content remained statistically the same during the whole storage period (60 days).

It has been reported that wheat flours do not contain HCN but these are present in a high concentration in raw flaxseed. The flaxseed flours used in the present study were prepared from the flaxseed grains subjected to microwave roasting before grinding. The microwave roasting of flaxseed significantly reduced the HCN content, thus making it fit for human consumption. The increase in HCN contents of composite flours may be attributed to the addition of flaxseed flour, which contributed more HCN in the respective composite wheat flour. The HCN contents of PDF fortified WWF and SGF were relatively lower than compared to FFF fortified WWF and SGF composite flours. Oomah and Mazza (1998) and Hussain *et al.* (2008) demonstrated that commercial processing like defattening and heat treatment (microwave roasting) could help in the reduction of the HCN content in flaxseed. Feng *et al.* (2003) also reported 83.2% reduction in HCN content of flaxseed due to microwave roasting. Thus reduction of HCN content in PDF fortified composite flours may be due to partial defattening treatment besides microwave roasting. The present study suggested that flaxseed must be roasted and partially defatted in order to get maximum reduction in HCN content.

Table 1. Effect of flaxseed fortification level and storage intervals on the cyanogenic glycosides (HCN) content of composite flours.[1,2]

	HCN (mg/kg)			
	WWF+PDF	WWF+FFF	SGF+PDF	SGF+FFF
Fortification level (%)				
0	0.00^{f}	0.00^{f}	0.01^{f}	0.01^{f}
4	0.07^{e}	0.073^{e}	0.07^{e}	0.08^{e}
8	0.13^{d}	0.15^{d}	0.13^{d}	0.15^{d}
12	0.18^{c}	0.27^{c}	0.19^{c}	0.27^{c}
16	0.30^{b}	0.35^{b}	0.32^{b}	0.36^{b}
20	0.37^{a}	0.44^{a}	0.39^{a}	0.44^{a}
Storage days				
0	0.18^{a}	0.22^{a}	0.19^{a}	0.22^{a}
30	0.17^{a}	0.21^{a}	0.18^{a}	0.22^{a}
60	0.17^{a}	0.21^{a}	0.17^{a}	0.21^{a}

[1] Means followed by the same superscript letters in fortification level or storage interval columns are not significantly different from each other.
[2] FFF = full fat flaxseed flour; PDF = partially defatted flaxseed flour; SGF = straight grade flour; WWF = whole wheat flour.

Peroxide value

There was a non-significant effect of both treatments (fortification levels) and storage intervals on the POV of composite flours. The lowest POV (0.64 mEq/kg) was recorded in 100% wheat flour and the highest (0.73 mEq/kg) POV was recorded in 20% PDF fortified WWF composite flour (Table 2). Similar result was recorded in the composite

Table 2. Effect of flaxseed fortification level and storage intervals on peroxide value of composite flours.[1,2]

	Peroxide value (mEq/kg)			
	WWF+PDF	WWF+FFF	SGF+PDF	SGF+FFF
Fortification level (%)				
0	0.64[a]	0.64[a]	0.82[a]	0.82[a]
4	0.65[a]	0.69[a]	0.82[a]	0.85[a]
8	0.66[a]	0.72[a]	0.83[a]	0.90[a]
12	0.69[a]	0.74[a]	0.87[a]	0.96[a]
16	0.72[a]	0.75[a]	0.91[a]	1.00[a]
20	0.73[a]	0.78[a]	0.92[a]	1.01[a]
Storage days				
0	0.66[a]	0.71[a]	0.83[a]	0.94[a]
30	0.68[a]	0.72[a]	0.86[a]	0.95[a]
60	0.72[a]	0.75[a]	0.90[a]	1.00[a]

[1] Means followed by the same superscript letters in fortification level or storage interval columns are not significantly different from each other.
[2] FFF = full fat flaxseed flour; PDF = partially defatted flaxseed flour; SGF = straight grade flour; WWF = whole wheat flour

flours fortified with FFF. The incorporation of FFF and PDF had non-significant effect on the POV of WWF and SGF composite flours. The onset of rancidity, which may be predicted from POV, has not been changed by increasing the level of flaxseed flour (PDF or FFF) in the composite flours. The POV ranged from 0.82 to 0.92 mEq/kg in PDF fortified SGF composite flours, while it varied from 0.82 to 1.01 mEq/kg in FFF fortified SGF composite flours.

The results in Table 2 indicate a non-significant effect of storage intervals on the POV of different composite flours. The POV of freshly stored composite flours (0 day) was recorded as 0.66, 0.71, 0.81 and 0.94 mEq/kg for PDF fortified WWF, FFF fortified WWF, PDF fortified SGF and FFF fortified SGF composite flours, respectively. There was a non-significant change in POV during storage up to 60 days. The risk of fat oxidation and development of rancidity increases if moisture content exceeds 12% (Kent and Evers, 1994), but in the present study moisture content of composite flours was recorded less than 12% (i.e. 8.63-11.30% for different blends).

The results of the present study are supported by the findings of Ratnayake *et al.* (1992) who reported that whole flaxseed grains or coarsely ground, showed long-term storage stability at room temperature and no changes in the POV after 308 days of storage at 22 °C. Daun (2001) also supported the storage stability of flaxseed and reported that peroxide levels were relatively unchanged and the alpha linolenic acid content was not affected in flaxseed packaged in loosely closed plastic bags and protected from light when stored in warehouse conditions at room temperatures for 20 months.

The POV of composite flours stored for 60 days was not significantly changed by the storage intervals. The moisture content found in composite flours was below the crucial limits as to facilitate the onset of rancidity. The flours were also stored in tin cans and were protected from light at room temperature. These factors might have helped to retain the flours stability with respect to their POV. Inclusion of flaxseed also contributed towards the stability of composite flours which might be due to the presence of tocopherols that served as natural antioxidants in the composite flour systems. The presence of tocopherol isomers like α, β, γ and δ and their antioxidant effectiveness is well supported by Oomah and Mazza (1997). Dessi *et al.* (2002) also reported that flaxseed oil also contained sterol like squalene (4 mg/100 g of oil) that may act as peroxy radical scavenger in high polyunsaturated fatty acid oils to protect it from oxidation. High content of natural antioxidant, i.e. tocopherols, present in flaxseed might have resulted the stability of composite flours during storage.

Mixographic studies

Peak height percentage

The highest peak height percentage, i.e. 47% was recorded in 100% WWF (control) and there was a decreasing trend in peak height percentage with increasing the level of PDF or FFF in WWF (Table 3). The lowest peak height parentages and 26.3% were recorded in whole wheat composite flours fortified with 20% FFF. The peak height percentage of whole wheat composite flours fortified with 8 and 12% FFF were found statistically at par with each other. Similarly whole

Table 3. Effect of flaxseed fortification on peak height percentage of composite flours.[1,2]

Fortification (% flaxseed flour)	Peak height percentage (%)			
	WWF+PDF	WWF+FFF	SGF+PDF	SGF+FFF
0	47.0[a]	47.0[a]	58.1[a]	58.1[a]
4	43.8[b]	37.9[b]	53.9[b]	47.5[b]
8	40.4[c]	34.6[c]	48.1[c]	42.9[c]
12	38.4[cd]	33.0[c]	43.8[d]	39.7[d]
16	36.1[d]	29.3[d]	38.3[e]	35.8[e]
20	31.4[e]	26.3[e]	35.7[e]	33.2[e]

[1] Means followed by the same superscript letters in a column are not significantly different from each other.
[2] FFF = full fat flaxseed flour; PDF = partially defatted flaxseed flour; SGF = straight grade flour; WWF = whole wheat flour.

wheat composite flours fortified with 12 and 16% PDF were found to be statistically non-significant with respect to peak height percentages.

The peak height showed similar trend with respect to flaxseed fortified straight grade composite flours as was found for flaxseed fortified WWF composite flour. The higher peak height percentage was recorded for 100% SGF. It decreased from 58.1 (100% SGF) to 37.5% (20% PDF fortified SGF) and to 32.0% (20% FFF fortified SGF). The peak height of flaxseed fortified SGF composite flours was higher than the peak height percentage of flaxseed fortified WWF composite flours.

There was a significant variation in peak height percentage as a function of storage among different composite flours. The results presented in Figure 1 illustrate that peak height percentage decreased significantly as the storage period progressed from 0 to 60 days. The peak height percentage decreased from 42.2 to 38.9% and 35.6 to 33.8% in whole wheat composite flours fortified with PDF and FFF, respectively during 60 days storage of composite flours. The peak height also decreased from 47.1 to 45.6% and 43.7 to 42% in SGF composite flours containing PDF and FFF, respectively when tested at the end of 60 days storage.

Butt *et al*. (1997) reported that peak height of different wheat varieties ranged from 43 to 65%. Similarly, Rasool (2004) reported that incorporation of non-wheat plant materials like cottonseeds resulted in the decrease in peak height of composite flours. Venketeswara *et al.* (1985) found that replacement of non-wheat flours with wheat flours resulted a decrease in gluten and dough stability. Singh *et al.* (2002) also showed the decrease in peak height percentage of wheat flour added with lactic acid and fat. Gujral and Singh (1999) concluded this decrease in peak height percentage of flour due to the reduction of SH groups. Koca and Anil (2007) also demonstrated a decline in the stability of dough by the addition of 15 and 20% flaxseed flour in the wheat flour which is identical to the results found in the present study. Seguchi *et al.* (2007) studied the effect of size of added cellulose granule on the peak height percentage of wheat flour and concluded that up to 154 μm size of cellulose does not affect the peak height of flour, while the dilution affect (decrease in gluten contents) due to addition of beans flour up to level of 20% was considered as the cause of decrease in peak height of composite flours (Hallen *et al.*, 2004). The present study suggested that due to increase in the level of flaxseed flours (defatted or full fat) in wheat flours (SGF and WWF), negative effect on rheological behaviours of the composite flours. This might be attributed to weakening of dough due to increase in non-gluten proteins contributed by higher levels of flaxseed flours. The high fat content contributed by flaxseed in composite flours might be another factor that resulted in the decline in peak height percentages of the composite flours observed in the present study. There is a significant decrease in peak height percentage of composite flours as a function of storage period which might be due to proteolytic activity of enzymes during storage as reported by Leelavathi *et al.* (1988).

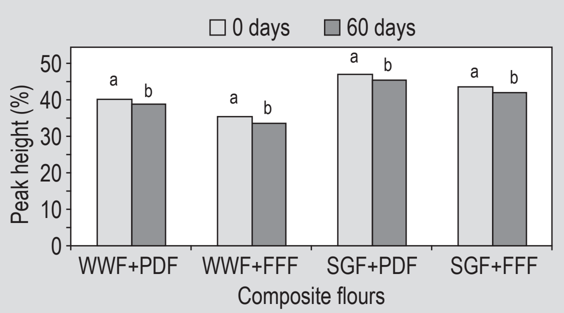

Figure 1. Effect of storage on peak height percentage of composite flours (FFF = full fat flaxseed flour; PDF = partially defatted flaxseed flour; SGF = straight grade flour; WWF = whole wheat flour). Different letters above the columns show a significant difference between 0 and 60 days of storage.

Mixing time

The results given in Table 4 indicate that mixing time decrease significantly among composite flours as the level of fortification of FFF or PDF increased in the WWF or SGF. The results explicated that the highest mixing time (3.7 min.) recorded for 100% WWF (control) which was decreased to 1.0 and 1.1 minutes in case of 20% PDF and FFF fortified WWF flours, respectively. The whole wheat composite flours containing 16 and 20% FFF yielded statistically at par mixing times i.e. 1.1. The mixing time for flaxseed fortified SGF composite flours also followed the

Table 4. Effect of flaxseed fortification on mixing time of composite flours.[1,2]

Fortification (% flaxseed flour)	Mixing time (minutes)			
	WWF+PDF	WWF+FFF	SGF+PDF	SGF+FFF
0	3.7^{a}	3.7^{a}	4.0^{a}	4.0^{a}
4	3.1^{b}	3.1^{b}	3.7^{b}	3.6^{b}
8	2.8^{c}	2.2^{c}	3.4^{c}	3.2^{c}
12	1.8^{d}	1.7^{d}	3.0^{d}	2.6^{d}
16	1.2^{e}	1.1^{e}	2.7^{e}	2.4^{de}
20	1.0^{f}	1.1^{e}	2.5^{e}	2.2^{e}

[1] Means followed by the same superscript letters in a column are not significantly different from each other.
[2] FFF = full fat flaxseed flour; PDF = partially defatted flaxseed flour; SGF = straight grade flour; WWF = whole wheat flour.

similar trend as was observed for WWF composite flours. The higher mixing time was recorded for 100% SGF. The mixing time decreased significantly as the level of PDF and FFF fortification increased in SGF. It is obvious from the results in Table 4 that mixing time of PDF fortified SGF decreased from 4.0 (100% SGF) to 2.5 minutes in SGF 20% PDF fortified SGF. The SGF fortified with 16 and 20% FFF had non-significant effect on mixing time. The flaxseed fortified WWF composite flours possessed significantly lower mixing time as compared to flaxseed fortified SGF composite flours.

The results illustrated in Figure 2 depicted that mixing time decrease as a function of storage period. The mixing time decreased from 2.3 to 2.2 and 2.2 to 2.1 in whole wheat composite flours fortified with PDF and FFF, respectively during 60 days storage. The mixing time also decreased from 3.3 to 3.1 and 3.1 to 2.9 in SGF composite flours fortified with PDF and FFF, respectively during 60 days storage. Lower mixing times were recorded in both types of composite flours after 60 days of storage interval while fresh samples exhibited the higher mixing times.

Mixing time is the time required for the curve to reach at its full development or maximum consistency possessing the highest peak. There is a relationship of high peak height with strong wheat's having long mixing time. The mixing time of wheat variety SH-2002 has been reported 3.7 minutes by Afzal (2004) which is close to the results of present study in which control wheat flours (WWF and SGF) yielded 3.7 and 4.0 minutes mixing times, respectively. The flaxseed flour fortification in wheat flour resulted in decrease in gluten forming proteins resulting in weakening of dough (Garden, 1993). The flaxseed fortification at 15 and 20% with wheat flour resulted in the weakening of dough and decrease in dough development time (Koca and Anil, 2007). Chen *et al.* (2003) found that replacing a part of the wheat flour with native and modified potato as well as sweet potato starches decreased the mixing time from 3.0 to 2.0 minutes. Dhingra and Jood (2004) also observed a decrease in the mixing time of composite flours due to increase in the level of soy and barley fortification. The decrease in mixing time of composite flours found in the present study may be due to decrease in their gluten contents, coarser nature of flaxseed flours added to wheat flours and weakening of protein network due to proteolytic activity during the storage of composite flours.

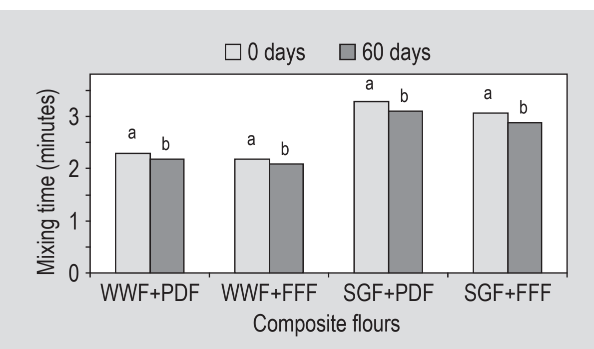

Figure 2. Effect of storage on mixing time of composite flours (FFF = full fat flaxseed flour; PDF = partially defatted flaxseed flour; SGF = straight grade flour; WWF = whole wheat flour). Different letters above the columns show a significant difference between 0 and 60 days of storage.

4. Conclusions

Flaxseed is a good source of dietary fibre, high quality proteins, minerals and essential fatty acids. Many studies have proved that flaxseed can be used to have many health benefits. The current study was planned to investigate the storage stability of flaxseed fortified flours. The flours are normally prepared and stored in bulk in developed countries for a long period of time. The stability and rheology of fortified flours with flaxseed can be a concern by the household consumers as well as the baking industry interested to use these flours. The outcome of the study highlights the effect of storage on antinutritional, stability and rheological parameters of flaxseed fortified flours. Based on the results of present studies, it can be concluded that flaxseed can be successfully incorporated in baked products. The rheological properties and storage stability are affected during storage studies of 60 days. The antinutritional factors were reduced during the storage of wheat flours.

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References

Addis, P.B and Warner, G.J., 1991. The potential aspects of lipid oxidation products in food. In: Auroma, O.I. and Halliwal, B. (eds.) Free radicals and food additives. Taylor and Francis, London, UK.

Afzal, B., 2004. Effect of different improvers on the functional properties of different wheat cultivars. MSc thesis, National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan.

American Association of Cereal Chemists (AACC), 2000. Approved methods of the AACC. AACC, St. Paul, MN, USA.

Association of Official Analytical Chemists (AOAC), 1990. Officials methods of analysis of AOAC International (15th Ed.). AOAC, Gaithersburg, MD, USA.

Baixuli, R., Sanz, T., Salvador, A. and Fiszman, S.M., 2007. Influence of the dosing process on the rheological and microstructural properties of a bakery product. Food Hydrocolloids 21: 230-236.

Barlow, S.N., 1990. Toxicological aspects of antioxidants used as food additives. In: Hudson, B.J.F. (ed.) Food antioxidants. Elsevier, Amsterdam, the Netherlands, pp. 253-307.

Blokshma, A.H. and Bushuk, W., 1988. Rheology and chemistry of dough. In: Pomarenz, Y. (ed.) Wheat chemistry and technology, volume 2. AACCI, St. Paul, MN, USA.

Butt, M.S., Anjum, F.M., Ali, A. and Rehman, A., 1997. Milling and baking properties of spring wheat. Journal of Agricultural Research 35: 403-412.

Chen, Z., Schols, H.A. and Voragen, A.G.J., 2003. The use of potato and sweet potato starches affects white salted noodle quality. Journal of Food Science 68: 2630-2637.

Daun, J.K., 2001. Storage stability of milled flaxseed. Journal of American Oil Chemists Society 38: 105-106.

Dessi, M.A., Deiana, M., Dat, B.W., Rosa A., Banni, S. and Corongiu, F.P., 2002. Oxidative stability of polyunsaturated fatty acids: effect of squalene. European Journal of Lipid Science and Technology 104: 506-512.

Dhingra, S. and Jood, S., 2004. Effect of flour blending on functional, baking and organoleptic characteristics of bread. International Journal of Food Science and Technolology 39: 213-222.

Feng, D., Shen, Y. and Chavez, E.R., 2003. Effectiveness of different processing methods in reducing hydrogen cyanide content of flaxseed. Journal of Science of Food Agriculture 83: 836-841.

Finney, K.F., 1984. An optimized straight-dough, bread making method after 44 years. Cereal Chemistry 621: 20-27.

Fitzpatrick, K., 2006. Plant based omega-3: chemistry, applications and potential health benefits. 97th AOCS Annual Meeting and Expo, April 30-May 3, 2006, America's Center, St. Louis, MO, USA.

Garden, J.A., 1993. Flaxseed gum: extraction, characterization and functionality. PhD thesis, North Dakota State University, Fargo, ND, USA.

Gujral, H.S. and Singh, N., 1999. Effect of additives on dough development gaseous release and bread making properties. Food Research International 32: 691-697.

Hallen. E., IIbanoglu, S. and Ainsworth, P., 2004. Effect of fermented/germinated cowpea flour addition on the rheological and baking properties of wheat flour. Journal of Food Engineering 63: 177-184.

Hurrell, R.F., 1997. Preventing iron deficiency through food fortification. Nutrition Review 55: 210-222.

Hussain, S., Anjum, F.M., Alamri, M.S., Mohammed, A.A. and Nadeem, M., 2013. Functional flaxseed in baking. Quality Assurance and Safety of Crops and Foods 5: 375-385.

Hussain, S., Anjum, F.M., Butt, M.S., Alamri, M.S. and Khan, M.R., 2012. Biochemical and nutritional evaluation of unleavened flat breads fortified with healthy flaxseed. International Journal of Agriculture and Biology 14: 190-196.

Hussain, S., Anjum, F.M., Butt, M.S., and Sheikh, M. A., 2008. Chemical compositions and functional properties of flaxseed flour. Sarhad Journal of Agriculture 24: 649-653.

Hussain, S., Anjum, F.M., Butt, M.S., Khan, M.I. and Asghar, A., 2006. Physical and sensoric attributes of flaxseed flour supplemented cookies. Turkish Journal of Biology 30: 87-92.

Kent, N.L. and Evers, A.D., 1994. Technology of cereals (4th Ed.). Pergamon Press, Oxford, UK.

Kirk, S.R. and Sawyer, R., 1991. Pearson's composition and analysis of foods (9th Ed.). Addison Wesley Longman Ltd, Harlow, UK.

Koca, A.F. and Anil, M., 2007. Effect of flaxseed and wheat flour blends on dough rheology and bread quality. Journal of Science of Food and Agriculture 87: 1172-1175.

Leelavathi, K. and Haridas Rao, P., 1988. Chapati from germinated flour. Journal of Food Science and Technology 25: 162-164.

Martin, J.R., 2004. Flax seed summary of storage and cooking stability studies. Available at: www.flaxrd.com.

Oomah, B.D. and Mazza, G., 1997. Effect of dehulling on chemical composition and physical properties of flaxseed. LWT – Food Science and Technology 30: 135-140.

Oomah, B.D. and Mazza, G., 1998. Flaxseed products for disease prevention. In: Mazza, G. (ed.) Functional foods: biochemical and processing aspects. Technomic Publishing, Lancaster, PA, USA, pp. 91-138.

Rasool, G., 2004. Characterization and evaluation of wheat flour enriched with oilseed proteins for chapatti making. PhD thesis, National Institute of Food Science and Technology, University of Agriculture, Faisalabad, Pakistan.

Ratnayake, W.M.N., Behrens, W.A., Fischer, P.W.F., L'Abbe, M.R., Mongeau, R. and Beare-Rogers, J.L., 1992. Flaxseed: chemical stability and nutritional properties. Journal of Nutrition and Biochemistry 3: 232-240.

Seguchi, M., Tabara, A., Fukawa, I., Ono, H., Kumashiro, C., Yoshino, Y., Kusunose, C. and Yamane, C., 2007. Effects of size of cellulose granules on dough rheology, microscopy, and bread making properties. Journal of Food Science 72: E79-E84.

Singh. N., Bajaj, I.K., Singh, R.P. and Gujral, H.S., 2002. Effect of different additives on mixograph and bread making properties of Indian wheat flour. Journal of Food Engineering 56: 89-95.

Steel, R.G.D., Torrie, J.H. and Dickey, D.A., 1997. Principles and procedures of statistics; a biometrical approach (3rd Ed.). McGraw Hill Book Co. Inc., New York, NY, USA.

Yang, H., Mao, Z. and Tan, H., 2004. Determination and removal methods for cyanogenic glycoside in flaxseed. American Society of Agricultural and Biological Engineers, St. Joseph, MI, USA.