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Effect of flaxseed incorporation on physical, sensorial, textural and chemical attributes of cookies

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Abstract

Considering the potential of flaxseed as functional ingredient, roasted flaxseed flour (RFF) was incorporated by substituting refined wheat flour at 5%, 10%, 15%, 25% and 30% in cookies formulations. Thickness and diameter of cookies increased as flaxseed flour was increased. Addition of flaxseed restricted the spread of cookies. 15% flaxseed flour incorporated cookies were found to be well comparable with control in sensory evaluation. Hardness and fracturability of experimental cookies increased up to 15% flaxseed flour incorporation. Thereafter, both these attributes showed decline trend. Chemical composition showed that moisture, ash, fat and protein content increased in flaxseed flour cookies than control. Fiber content was nine times more in flaxseed flour cookies than the control. Alpha linolenic acid (ALA) content increased from 0.19% (control) to 4.76% in optimized cookies. An improvement in polyunsaturated to saturated fatty acid ratio was observed while ω-6 to ω-3 fatty acid found to be decreased to well below maximum recommended value.

Introduction

Today foods are not intended to only satisfy hunger and to provide necessary nutrients for humans but also to prevent nutrition-related diseases and improve physical and mental well-being (Nothlings *et al.*, 2007; Takachi *et al.*, 2008). Functional foods are quiet remedy. To develop functional foods, professionals are always exploring the abilities of different food ingredients/crops. Among several food crops, in the last two decade, flaxseed has emerged as one of the important and attractive functional food ingredient from several reported scientific literature due to owing the desirable nutrient composition. Flaxseed, or Linseed (*Linum Usitatissimmum*), popularly known as Alsi, Jawas, Aksebija in Indian languages, is a blue flowering rabi crop and a member of family Linaceae (Ganorkar and Jain, 2013). Proximate composition of flaxseed revealed that it is rich source of ALA (omega-3, polyunsaturated fatty acid), protein, dietary fiber and lignan (Hettiarachchy *et al.*, 1990; Nagraj, 1995; Madhusudhan *et al.*, 2000; Fritsche *et al.*, 2002; Morris, 2007; Husain, 2008; Singh and Jood, 2009). Flaxseed oil or blends of flaxseed oil and sunflower oil promoted cholesterol reduction in hyper-cholesterolemic rats compared to diets formulated with hard fats (Ranhotra *et al.*, 1993). Flaxseed protein was effective in lowering plasma cholesterol and triglycerides (TAG) compared to soy protein and casein protein (Bhathena *et al.*, 2002). Flaxseed is a rich source of dietary fiber (accounting 28%), both soluble as well as insoluble fibers (Morris, 2007). Soluble fiber and other components of flaxseed fraction could potentially affect insulin secretion and its mechanism of action in maintaining plasma glucose homeostasis. Lignans have antioxidant activity and thus may contribute to the anticancer activity of flaxseed (Prasad, 1997; Yuan *et al.*, 1999; Kangas *et al.*, 2002).

Baking industry is one of the largest organized processed food industries. The popularity of the bakery products is mainly due to their ready-to-eat nature, convenience, low cost and available in large number of varieties of different tastes and textural profiles. The main advantage of bakery products is their amenability for fortification with cereals, millets or other functional ingredients. Commercially available cookies are particularly deficient in ALA, dietary fiber and lignan. Flaxseed is a treasure trove of nutrients and nutraceuticals with established health benefits in human being. Considering the potential of flaxseed as functional ingredient, its exploration in the food product still appears to be limited. Therefore, the present investigation had undertaken to develop flaxseed incorporated cookies.

Materials and Methods

Flaxseed

Flaxseed (Variety NL 260) was procured from College of Agriculture, Nagpur, MS, India. Flaxseed were roasted in microwave oven with 580 W output,

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under the operating frequency of 2450 MHz for 300 seconds to get nutty flavour. Roasted flaxseed were ground in domestic mixer and passed through 400 µ sieve.

Refined wheat flour

Uttam brand commercial refined wheat flour (M/s Uttam flour Mill) was procured from local market. The refined wheat flour characteristics like Moisture (method 44–16), ash (method 08-01), dry gluten (method 38-10) were determined using the methods of AACC (2000).

Ingredients

Raag brand shortening, Sagar brand milk powder, Wiekfield brand custard powder, blue bird baking powder, saffron pista essence, powdered sugar were used in the present studies.

Preparation of cookies

Cookies were prepared by substituting 0, 5, 10, 15, 20, 25 and 30 per cent refined wheat flour with roasted flaxseed flour (RFF). Refined wheat flour (100 g for control cookies), custard powder (2 g), baking powder (0.5 g) and RFF (in experimental samples) were mixed together. Powdered sugar (50 g) and shortening (60 g) and essence were creamed together for 5 min to get bright and fluffy mass. Milk (5 ml) was added in to the mass and mixed well. Dry ingredients were slowly added in to creamed fluffy mass and mixed well for 2 min. The cookie dough was sheeted to 8 mm thickness and cut into circular shape using 42 mm diameter cutter. The cookies were then baked at 180°C for 15 min. The cookies were cooled for 10 minutes, then wrapped in aluminum foil and packed in polyethylene bag (Kamaliya and Kamaliya, 2001; Rajiv *et al*., 2012).

Evaluation of cookies for Physical characteristics

Diameter (D), thickness (T) and spread ratio were analyzed as physical characteristics for control and cookies with RFF. For the determination of cookies diameter (D), six cookies were placed edge to edge. The total diameter of the six randomly selected cookies was measured in mm by using a ruler. The cookies were rotated at an angle of 90° for duplicate reading. The average diameter was reported in mm. To determine the thickness (T), six cookies were placed on top of another. The total height was measured in mm with the help of ruler. This was repeated thrice to get an average value and results are reported in mm. Spread ratio was determined with the help of following formula:

$$Spread\ ratio = \frac{Average\ diameter\ (mm)}{Average\ thickness\ (mm)}\ x10$$

Sensory evaluation of cookies

Sensory evaluation was carried out by a panel of ten semi trained panel members. Hedonic rating test was employed using 9-point hedonic scale. Sensory parameters such as color, taste, texture and overall acceptability were evaluated (Ranganna, 2000).

Texture analysis

Prepared cookies were analyzed for the effect of refined wheat flour replacement with roasted flaxseed flour for its hardness and fracturability using Texture analyzer (Stable Microsystems, UK, Model TA-HDi). Hardness and fracturability of the cookies were measured by triple beam snap setup (Gaines, 1991). Load cell of 5 kg, 3 mm/s test speed and 5 mm travel distance were used. The sample was placed on two supporting beams aparted by 3 cm distance. Another beam connected to moving part was brought down to break down the biscuit. Mean value of three determinations are reported.

Proximate analysis

Roasted flaxseed flour, control cookies and RFF incorporated cookies were analyzed for moisture, ash, crude protein, fat and crude fiber according to methods described in AACC (2000).

Fatty acid profile analysis

It was carried out by Gas Chromatography instrument (Make – Perkin Elmer, Model – Auto System XL) according to the method suggested by Petrovic *et al.* (2010).

Statistical analysis

Data was analyzed with Daniel's XL Toolbox Version 5.08 using one – way analysis of variances (ANOVA) with tukey's comparision of means values. Differences between mean values with probability $p < 0.05$ were recognized as statistically significant differences.

Results and Discussion

The refined wheat flour had 9.32% moisture, 0.48% ash 8.1% dry gluten and 8.7% protein. Lower gluten content refined wheat flour is most suitable for cookies preparation (Miller *et al*., 1997). The roasted flaxseed flour had the chemical composition as 3.6% moisture content, ash 4.1%, protein 21.1%, fat 44.3% and crude fiber 12.3%. Fatty acid profile of

Table 1. Physical characteristics of control and RFF incorporated cookies

Treatment	Thickness	Diameter	Spread ratio
Control	50.33 ± 0.76[a]	286.75 ± 0.96[a]	5.70 ± 0.07[a]
5% RFF	51.33 ± 0.29[a]	288.5 ± 1.00[ab]	5.62 ± 0.03[a]
10% RFF	54.33 ± 0.58[b]	290.25 ± 0.96[b]	5.34 ± 0.04[b]
15% RFF	55.33 ± 0.58[b]	295.75 ± 0.50[c]	5.35 ± 0.05[b]
20% RFF	62 ± 1.32[c]	311.25 ± 0.96[d]	5.02 ± 0.09[c]
25% RFF	65.33 ± 1.5[d]	315.25 ± 0.96[e]	4.83 ± 0.10[d]
30% RFF	69.33 ± 1.15[e]	321.25 ± 0.96[f]	4.63 ± 0.06[d]

Mean values in the same column which is not followed by the same superscript letter are significantly different (p<0.05).

Table 2. Sensory score of control and RFF cookies

Sample Code	Color	Taste	Texture	Overall Acceptability
Control	8.1[a]	7.9[a]	8.3[a]	8[a]
A	7.9[ab]	7.7[a]	8.1[ab]	7.8[a]
B	7.3[bc]	7.5[a]	7.6[bc]	7.7[a]
C	7[cd]	7.4[a]	7.2[c]	7.5[a]
D	6.3[de]	6.4[b]	6.4[d]	6.5[b]
E	5.6[e]	4.5[c]	5.6[e]	5.1[c]
F	4.3[f]	3.9[c]	4.6[f]	4.3[d]

Mean values in the same column which is not followed by the same superscript letter are significantly different (p<0.05).

roasted flaxseed oil (Table 4) revealed that it is rich source of ALA (55.37%) and linoleic acid (11.38%). Several other researchers reported similar results. (Rajiv *et al.*, 2012; Masoodi *et al.*, 2012; Chetana *et al.*, 2010; Singh and Jood, 2009; Husain, 2008). Some variations were observed. This might be due to varietal and growing environmental conditions difference effect on wheat and flaxseed cultivar.

Effect of refined wheat flour replacement with roasted flaxseed flour on physical characteristics of cookies

The physical characteristics of seven types of cookies are shown in Table 1. Results of these studies indicated that there is significant difference ($p < 0.05$) between control sample and treated samples except 5% RFF flour sample. As RFF level increased, thickness and diameter of cookies increased. Protein influences the dough viscosity. This is because the expansion of protein gluten is not resumed in the making of cookies. Inverse correlation was obtained between diameter and protein content (Leon *et al.*, 1996). Protein gluten in flour will form a web in cookie dough when heated. During baking, the gluten goes through an apparent glass transition, thereby, gaining mobility that allows it to interact and form a web. The formation continuous web increases viscosity and stops the flow of cookie dough (Miller *et al.*, 1997). Lowest thickness of 50 ± 0.76 mm and diameter of 286.75 ± 0.96 of control while highest thickness of 69.33 ± 1.15 mm and diameter of 321.25 ± 0.96 at 30% RFF were observed in cookies.

As the RFF level increased, spread ratio for different treated cookies gradually decreased from 5.70 ± 0.07 to 4.63 ± 0.06. This reduction in spread ratio might be due to increase in protein and dietary fiber percentage with increasing level of flaxseed flour because protein and dietary fiber has more water binding power. When more water is present in the dough, more sugar is dissolved during mixing. This lowers the initial dough viscosity and the cookie is able to spread at a faster rate during heating. The flour components that absorb large quantities of water reduce the amount of water that is available to dissolve the sugar in the formula. Thus, initial viscosity is higher and the cookies spread less during baking (Hoseney and Rodger, 1994). Cookie spread rate appears to be controlled by dough viscosity (Yamazaki, 1959). It is the reason due to which soft wheat varieties are recommended with low protein content to prepare cookies (Miller *et al.*, 1997). Hoojat and Zebik (1984) also showed that 20% and 30% replacement of navy bean, sesame flour reduced the spread factor of the wheat flour cookies.

Effect of refined wheat flour replacement with roasted flaxseed flour on sensory attributes of cookies

Mean score of sensory attributes (Color, Taste, Texture and Overall acceptability) for control and RFF cookies is presented in Table 2. Color score results for control and different treated samples indicate that the score decreased with increasing content of RFF. The probable reason for these results could be brown color of flaxseed which became dark brown at high baking temperature. Pigments such as leutin/zeaxanthin in flaxseed makes it dark brown (United States Department of Agriculture, 2007). Maillard reaction may have also contributed to the darker color of bakery products due to the high protein content of flaxseed (Borrelli *et al.*, 2003). Taste of the cookies was considerably influenced due to flaxseed incorporation. Results reveals that there was no significant difference ($p < 0.05$) in taste up to 15% incorporation of flaxseed cookies and control sample cookies. At 5%, 10% and 15% RFF cookies, flaxseed pleasant nutty flavor is liked by judges. Beyond 15% RFF level, taste score significantly reduced. This might be due to unacceptable high nutty flavour imparted by RFF. Texture score values also showed decrease trend as RFF in cookies increased. This might be due to decrease in crispiness. 5% RFF sample texture was not significantly differed from control sample. But, afterwards significant difference was found. Overall acceptability score suggested that up to 15% RFF incorporated cookies were not significantly different than that of control. Overall acceptability is governed by all dominant sensory quality attributes. At 20% and above RFF incorporation level, overall acceptability score decreased significantly ($p < 0.05$). The reasoning behind this could be attributed to intensified flaxseed nutty flavor, unpleasurable after taste, dark brownish color, rough surface, less crisp and gritty mouth feel, making them to score low in sensory evaluation.

Table 3. Proximate composition of control cookies and RFF cookies

Parameter	Control Cookies*	RFF fortified cookies*
Moisture (wb), %	5.02±0.42[a]	6.33±0.54[b]
Ash, %	0.43±0.10[c]	0.82±0.11[d]
Protein (N x 6.25), %	5.86±0.63[e]	8.66±0.74[f]
Fat, %	31.13±1.15[g]	33.73±1.18[g]
Crude fibre, %	0.19±0.05[h]	1.72±0.22[i]
Carbohydrate**, %	57.55±1.30[j]	50.47±2.17[k]

Mean values followed by the same superscript alphabet in the row are not significantly different at $p < 0.05$.
*-Reported values are the average of three determinations, **- Carbohydrate is determined by difference

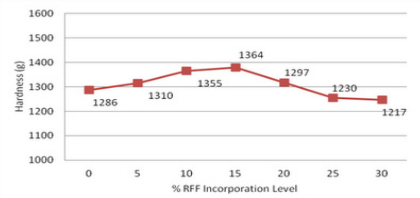

Figure 1. Effect of RFF incorporation level on hardness of cookies

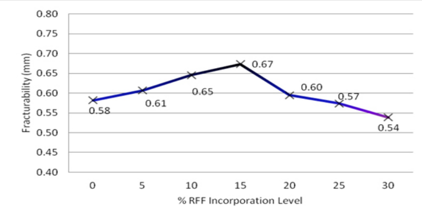

Figure 2. Effect of RFF incorporation level on fractuability of cookies

From the above discussion, RFF substitution at moderate levels (up to 15%) has resulted in acceptable products which were comparable with the control treatment. Chetana *et al.* (2010) reported that muffins incorporated with 20% roasted flaxseed had better overall acceptable quality. Husain (2006) also reported that cookies containing 20% and lower levels of flaxseed flour were acceptable. Variations in the results can be attributed to the flaxseed growing environmental conditions and variety used.

Effect of refined wheat flour replacement with roasted flaxseed flour on textural attributes of cookies

The instrumental textural attribute analysis was conducted to confirm the textural score as obtained from subjective evaluation of texture. The effect of incorporation of RFF on the textural attributes i.e. hardness (g) and fracturability (mm) are represented in figure 1 and 2, respectively. An increasing trend was observed for both the textural parameters up to 15% level of RFF flour incorporation and after that the textural parameters were found to decrease with increase in RFF incorporation. This observation is contradictory to the results reported by Rajiv *et al.* (2012) for breaking strength of flaxseed cookies. Since RFF has both gum mucilage (fiber) and protein, high water absorbing capacity components as well as there was a significant level of fat (around 41%) found in RFF, hence both these factors contributed in a sticky dough thus reducing extensibility of dough. The extensible and cohesive structure is contributed by sugar or water interaction with wheat protein thus forming gluten but with an increase in fat content the flour gets coated and this network gets interrupted thus properties of cookies are changed and a less harder. At very high fat content the lubricating function is high thus less water is required and a softer texture is obtained. Hence the hardness and fracturability gradually decreased forming softer cookies with an increased level of RFF flour. The values of hardness (g) and fracturability (mm) varied from 1217 ± 43 – 1364 ± 64 and 0.54 ± 0.01 – 0.67 ± 0.04, respectively. Sensory texture score might be decreased due to lower hardness and fracturability values which confirmed more softness at higher RFF incorporation level. Barnwal *et al.* (2013) reported similar results for partially de-oiled maize germ cake (DMGC) flour incorporated biscuits. They reported that the textural properties such as fracture force (N), hardness (N), breaking strength (N), breaking energy (N-mm), cutting strength (N) and cutting energy (N-mm) increased with DMGC flour incorporation level up to 30% but above 30% , decreased the values for textural attributes.

Table 4. Fatty acid profile of RFF oil, control cookies and RFF cookies oil

Fatty acid	RFF oil (Relative %)	Control cookies oil (Relative %)	RFF cookies oil (Relative %)
Myristic acid (S)	--	1.15	1.02
Palmitic acid (S)	6.49	45.20	40.92
Palmitolic acid (MUFA)	--	--	0.12
Stearic acid (MUFA)	5.55	5.92	5.95
Oleic acid (MUFA)	20.36	41.30	40.22
Trans oleic acid	0.76	0.35	0.33
Linoleic acid (ω-6 PUFA)	11.48	2.36	3.46
Linolenic acid (ω-3 PUFA)	55.37	0.19	4.76
Other fatty acids	--	3.53	3.22
Σ S	6.49	46.35	41.94
Σ PUFA	66.85	2.35	8.22
PUFA/S ratio	10.30	0.05	0.20
ω-6/ ω-3 ratio	0.21	12.42	0.72

S – saturated fatty acid, MUFA – Monounsaturated fatty acids, PUFA- Polyunsaturated fatty acids

Effect of flaxseed incorporation on chemical composition of cookies

Proximate analysis of control cookies and RFF incorporated cookies are presented in Table 3. Moisture content of RFF cookies increased (5.02%) as compared with control cookies (6.32%). This can be attributed to fiber (gum mucilage) present in flaxseed which has higher moisture retention property (Cui and Mazza, 1996). Ash content of RFF cookies (0.82%) increased as compared with control cookies (0.43%). This might be due to higher mineral content of flaxseed flour (Morris, 2003). Moreover, fat content (33.72%), protein content (8.66%) and crude fiber (1.73%) of RFF cookies increased as compared with control cookies. This could be accounted by the fact that flaxseed is far higher in fat, protein and crude fiber content compared with refined wheat flour as their proximate analysis is mentioned previously. Chetana *et al.* (2010) reported similar results for flaxseed incorporated muffins. Gambus *et al.* (2004) also observed that bread with 10 and 13% share of flaxseeds was characterized by higher amounts of protein, fat, dietary fiber, macro- and microelements in comparison to standard one.

Fatty acid profile of extracted oil from RFF, control cookies and 15% RFF incorporated cookies are depicted in Table 4. RFF oil was found to contain dominantly ALA (55.37%) followed by oleic acid, linoleic acid, palmitic acid and stearic acid. Comparison of control and RFF cookies oil fatty acid profile revealed that total saturated fatty acid content (ΣS) decreased from 46.35% to 41.94% while total polyunsaturated fatty acid content (ΣPUFA) increased from 2.35% to 8.22%. It was worthy to note an increase in ALA content from 0.19% to 4.76% was observed. Hence, as a baking ingredient, ground flaxseed does not lose significant amounts of ALA during baking. Chen *et al.* (1994) also reported that flaxseed lipid was stable during baking of flaxseed muffins. Bilek and Turhan (2009) also reported that flaxseed flour can be used as functional ingredient in beef patties as ALA content of raw and cooked beef patties increased with the increase in flaxseed flour addition. The two main parameters currently used to assess nutritional quality of the lipid fraction of foods are the ratios between polyunsaturated and saturated (P/S) and between omega- 6 and omega-3 fatty acids. Accordingly, to improve the health status of the population, the nutritional authorities have recommended regulating the consumption of foods rich in ω-3 PUFAs, in such a way that ω- 6/ω-3 PUFA ratio of less than 4 can be achieved and that the P/S ratio is higher than 0.4 (Wood et al., 2004). The obtained P/S ratio of RFF cookies (0.20) was nearer to the recommended ratio (>0.4) while ω- 6/ω-3 PUFA ratio of 0.72 was observed in RFF cookies which was well below than the recommended ratio of 4. Similar results are reported by Pelser *et al.* (2007) for dutch style fermented sausages after incorporation of flaxseed oil and canola oil.

Conclusion

The incorporation of RFF from 5 to 30% with refined wheat flour decreased spread ratio, color and sensory score. Above 15% of RFF incorporation, cookies quality adversely affected. Thus, 15% incorporation level of RFF in cookies resulted in acceptable product. It can be concluded from proximate analysis of cookies that most desirable nutrients like protein and fat content increased significantly. Dietary fiber content can be correlated with crude fiber content. Crude fiber content increased in RFF incorporated cookies which is beneficial for health. Flaxseed fortification in cookies resulted in the improvement of P/S ratio while ω-6/ω-3 PUFA ratio decreased below the maximum recommended ratio. Therefore, improvement in the nutritional status of RFF cookies without affecting on sensory attributes establishes the suitability of flaxseed use in bakery and other food products.

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