Technological, physico-chemical and sensory properties of raw and cooked meat batter incorporated with various levels of cold milled flaxseed powder

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Abstract Flaxseed has been proven for its multidimensional health benefits and can be used for development of emulsion type functional meat products. In view of this the incorporation of cold milled flaxseed powder (FSP) in meat batter at level 1–5 % was investigated. The results revealed that incorporation significantly ($P < 0.05$) decreased the total fluid release (TFR), fat release (FR) and water release (WR) of raw meat batter. The surface and internal color values were differed significantly ($P < 0.05$) among treatments at initial as well as during refrigerated storage period. Texture values especially hardness and chewiness values were found less ($P < 0.05$) in FSP treated samples and textural properties in FSP treated samples were not deteriorated during storage as compared to control samples. Thus incorporation of FSP had some beneficial effects on physico-chemical properties and textural properties which were also stable during storage period. However the redness values and sensory scores were observed less in FSP treated samples.

Keywords Meat · Flaxseed powder · Technological · Sensory · Texture profile

Introduction

Development and quality improvement of processed meat products with proven functional ingredients is an area of interest for meat processors. Such meat products can be developed using designer meat obtained either through pre-slaughter strategies i.e. through feeding or via post slaughter strategies i.e. through incorporation of functional ingredients in meat product formulations. Abundant research has been going on for alteration of meat composition through feeding (Bartoň et al. 2007; Juárez et al. 2011; Raes et al. 2003), but not succeeded to desired mark because of low digestibility, low absorbance through gut membrane, possible multifaceted interaction with other compounds or degradation of principal compound of interest due to enzymatic and chemical reactions in animal physiological system. Thus, there has been an increasing interest in the use of proven functional ingredients with multidimensional health benefits in the product formulation in order to improve the nutritional and functional value of meat products.

Flaxseed has recently gained attention as a *functional food* because of its unique nutrient profile. It is rich in lignans with high omega-3 fatty acid content. The phenolic compounds of interest that are accumulated in flaxseed include ferulic and vanillic acid (Siger et al. 2008). The beneficial effects of lignans on human health are well recognized (McCann et al. 2005). Flaxseed has potential to reduce the risk of cardiovascular diseases and some cancers, particularly hormone dependent cancers such as prostate and breast cancer. It has been reported to act as anti-arrhythmic (Ander et al. 2004), anti-atherogenic (Dupasquier et al. 2006; Dupasquier et al. 2007), and anti-inflammatory (Dupasquier et al. 2007) in addition to improving vascular function (Dupasquier et al. 2006).

There is more information on the use of flaxseed in bakery products (Conforti and Davis 2006; Koca and Anil 2007; Ramcharitar et al. 2005; Shearer and Davies 2005) and flaxseed oil has also been used in bakery (Shearer and Davies 2005) and meat products (Pelser et al. 2007; Valencia et al.

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2008). Pelser et al. (2007) studied the effect of addition of flaxseed oil, canola oil, encapsulated fish oil and encapsulated flaxseed oil in Dutch style fermented sausages and suggested possibility of replacing part of the animal back fat by health promoting oils giving fermented sausages a healthy image. However there is lack of research evaluating the effect of flaxseed powder incorporation on temporal changes in color, texture and oxidative properties of meat products.

The modification in products formulation has been shown some positive or negative effects on technological, physico-chemical and sensory properties of meat products like cooking properties, color and texture profile. Thus the main objective of this study was to assess the technological, physico-chemical and sensory properties of raw and cooked meat batter incorporated with various level of cold milled flaxseed powder.

Material and methods

Materials

Boneless broiler chicken meat was obtained from local meat market (6 week of age; 1 h postmortem) and kept in refrigeration for 4 h. Cold milled flaxseed powder was obtained from Prano Flax (India) Pvt. Ltd. All other chemicals used in the study were of analytical grade and purchased from Sigma unless otherwise mentioned. Flaxseed powder contained 33 % total fat (9.2 saturated; 20.4 % monounsaturated and 66.9 % polyunsaturated fatty acids), 32 % total carbohydrates and 19.3 % protein contents.

Preparation of meat batter with flaxseed powder

All visible fat and connective tissues were separated from chicken meat and it was minced through meat mincer (Sirman, Italy) by 8 mm plate. Four blends were formulated by combining minced meat with 5 %, 2.5 %, 1 % and 0 % (Control) flaxseed powder (FSP) by weight proportion, in all blends minced meat was homogenised with 2 % salt for 2 min, after waiting for 3 min 10 % chilled water was added and homogenized for 2 min. At last 10 % vegetable oil was added and homogenized for 2 min. After 3 min the batters were chopped for an additional 2 min; batter temperature did not exceed 12 °C in any of the treatments. Batters were formulated in triplicate and three measurements were done for each parameter in each replication. Samples were cooked at 140 °C for 20 min for color and texture parameters analysis. For storage study samples for each day analysis were packaged separately in low density polyethylene (LDPE) and kept under refrigeration for 8 day.

Proximate analysis and pH

Moisture, protein, ash and fat content were determined according to AOAC (2000). The carbohydrate content was obtained by subtracting the percent total of the moisture, fat, protein and ash contents from 100. The pH was determined by blending 10 g sample with 50 ml distilled water for 60 s in a homogenizer. The pH values were measured using a standardized electrode attached to a digital pH meter (Eutech instruments cyberscan pH tutor, India).

Emulsion stability and cooking loss

The batters were stuffed into plastic tubes (diameter 2.5 cm, and approximately 13.15 g) and centrifuged (2,500 g, 3 °C, 15 min) (MP 400R Eltek Ltd., India). Finally, the tubes with the samples were hermetically closed and heated in a water bath for 30 min at 70 °C. The tubes containing the different samples were opened and left to stand upside down (for 1 h) to release the exudates onto a plate. Emulsion stability, as total fluid release (TFR), was expressed as g/100 g of initial sample weight. Water release (WR) was determined as weight loss after heating the total released fluid for 16 h in an oven at 105 °C and expressed as g/100 g of initial sample weight. Fat release (FR) was calculated as the difference between TFR and WR. Cooking loss was calculated as per Yogesh et al.(2013).

Sensory evaluation

Sensory evaluation was carried out by an 8-member panel of judges drawn from scientists and postgraduate students of Central Institute of Post Harvest Engineering and Technology who are familiar with meat products. Raw meat batters were cooked as previously described and the cooked meat products were assessed for the appearance, odor, juiciness, texture, and overall acceptability using an 8 point Hedonic scale, where 1 represented dislike extremely and 8 represented like extremely. Each attribute was discussed and tests were initiated after the panellists were familiarized with the attributes and scales.

Texture profile analysis

Texture profile analysis (TPA) was performed in a *TA-HDi* Texture Analyzer (Stable Micro Systems LTD., UK) and the attributes were calculated as described by Bourne (1978). Three determinations per formulation of cooked (140 °C for 20 min) meat batter (2.5×2.5×2.5 cm) were compressed to 40 % of their original height. Force-time deformation curves were derived with a 50 Kg load cell applied at a constant crosshead speed of 1 mm/s. Attributes were calculated as follows. Hardness (Hd): peak force (N) required for first

compression; cohesiveness (Ch): ratio of active work done under the second compression curve to that done under the first compression curve (dimensionless); springiness (Sp): distance (mm) of sample recovery after the first compression; and chewiness (Cw): $Hd \times Ch \times Sp$ (N mm). All textural measurements were carried out at room temperature.

Color properties

Color measurement was carried out using a Hunter Colorimeter model 45/0-L mini scan XE PLUS (Hunter Associates Labs, Reston, VA, USA) on the basis of three variables, namely, L, a, and b. The instrument was calibrated against a standard black as well as white reference tile.

The raw and cooked samples were positioned directly on the light path to measure the color parameter values of L, a and b. In cooked samples surface color values as well as internal color values (1 cm inside) were determined. Four color readings were taken from each replication for surface and internal color determination.

Estimation of oxidative stability

The thiobarbituric acid reactive substances (TBARS) were determined from d0 to d8 by using the extraction method (Witte et al. 1970) with slight modification. Four g sample was homogenized with 20 % trichloroacetic acid solution (20 ml) and the slurry was centrifuge at 3,000 g (MP 400R Eltek Ltd., India) for 10 min. Two ml of supernatant was mixed with equal volume of freshly prepared 0.1 % thiobarbituric acid in glass test tubes and heated in water bath at 100 °C for 30 min followed by cooling under tap water. The absorbance of the mixture was measured at 532 nm and the TBARS values were calculated using a TEPP standard curve and expressed in mg malonaldehyde/kg.

Statistical analysis

The experiment was replicated thrice with three measurements in each replication unless otherwise mentioned and the data were analyzed by one-way analysis of variance for treatment effect and differences among the group means were compared using Duncan's test. A significance level of 0.05 was chosen. Data for color, texture attributes and TBARS values were also analyzed as days means as a group to evaluate the effect of storage period independent of other treatment.

Results and discussion

Proximate analysis and pH of raw meat batter

Data for proximate analysis and pH values of raw meat batter incorporated with various levels of FSP is presented in Table 1. All the parameters were differed significantly ($P < 0.05$) due to the main treatment effect except protein contents which were nonsignificant between different samples. Addition of FSP has been associated with reduction ($P < 0.05$) in moisture content which may be due to lower moisture content of FSP. Fat, carbohydrate and ash contents were increased due to the main effect of FSP level among different samples. Similar results were obtained by Turhan et al. (2005) for beef burgers formulated with hazelnut pellicle and by Elif Bilek and Turhan (2009) in the beef patty formulated with flaxseed flour. The pH values also differed significantly between different samples. Meltem (2006) reported similar results for meatballs made with the addition of whey powder. The pH of meat shown to be closely associated with water binding properties of meat proteins but other factors like isoelectric point and type and amount of water also determined the water binding properties of meat (Lonergan and Lonergan 2005).

Emulsion stability, cooking loss and color properties of raw meat batter

TFR, FR, WR were differed significantly ($P < 0.05$) between different samples (Table 1). The values for TFR were observed less in 5 % FSP incorporated samples and maximum TFR were observed in control samples. Thus TFR as a measure of emulsion stability indicated that incorporation of FSP might be involved in stabilization of meat matrix which might be due to the presence of emulsifiers in FSP proteins or carbohydrates. Previously it has also been shown that flaxseed protein concentrate has better water and oil absorption, emulsifying activity and emulsion stability of some emulsion systems (Wang et al. 2010; Dev and Quensel 1988; Dev and Quensel 1989). Likewise due to more emulsion stability in FSP incorporated samples FR and WR values were also observed less in these treatments as compared to control. Keeping fat within the matrix of meat products during processing is necessary to ensure sensory quality and acceptability (Serdaroğlu and Değirmencioğlu 2004). However presence of more fat especially polyunsaturated fatty acids resulted in more oxidative damage (see next sections).

Emulsions play critical roles in many forms of processing in food industry such as dairy products, beverage, sauce, soup, and butter (Utada et al. 2005; Guzey et al. 2004). Oil dispersions in the form of small spherical droplets are stabilized in aqueous phase by protein in an oil-in-water (O/W) emulsion.

Table 1 Effect of flaxseed powder (FSP) incorporation on physicochemical properties of raw meat batter (mean $\pm$ SD) ($n=9$ for all parameters; $n=12$ for color L, a and b values)

Parameters	FSP Level			
	5 %	2.5 %	1 %	Control
Moisture (%)	57.8 $\pm$ 0.58 ^c	59.5 $\pm$ 0.57 ^b	60.6 $\pm$ 0.77 ^a	60.9 $\pm$ 0.52 ^a
Protein (%)	19.4 $\pm$ 0.46	19.5 $\pm$ 0.49	19.4 $\pm$ 0.50	19.5 $\pm$ 0.44
Carbohydrates (%)	4.5 $\pm$ 0.12 ^a	3.7 $\pm$ 0.07 ^b	3.4 $\pm$ 0.09 ^c	3.1 $\pm$ 0.09 ^d
Fat (%)	15.5 $\pm$ 0.35 ^a	14.7 $\pm$ 0.43 ^b	14.1 $\pm$ 0.61 ^{bc}	14.0 $\pm$ 0.47 ^c
Ash (%)	2.8 $\pm$ 0.06 ^a	2.7 $\pm$ 0.02 ^b	2.6 $\pm$ 0.05 ^c	2.5 $\pm$ 0.04 ^c
TFR (%)	5.6 $\pm$ 0.07 ^d	6.0 $\pm$ 0.16 ^c	7.1 $\pm$ 0.19 ^b	8.0 $\pm$ 0.13 ^a
FR (%)	0.93 $\pm$ 0.07 ^c	1.15 $\pm$ 0.03 ^b	1.21 $\pm$ 0.04 ^b	1.31 $\pm$ 0.05 ^a
WR (%)	4.7 $\pm$ 0.10 ^d	4.9 $\pm$ 0.13 ^c	5.9 $\pm$ 0.22 ^b	6.7 $\pm$ 0.12 ^a
Cooking Loss (%)	11.5 $\pm$ 0.19 ^b	11.3 $\pm$ 0.16 ^b	11.6 $\pm$ 0.66 ^b	12.1 $\pm$ 0.32 ^a
pH	5.81 $\pm$ 0.01 ^a	5.77 $\pm$ 0.01 ^b	5.75 $\pm$ 0.01 ^c	5.74 $\pm$ 0.01 ^c
L	55.08 $\pm$ 0.92 ^d	57.53 $\pm$ 1.02 ^c	60.49 $\pm$ 1.84 ^b	66.22 $\pm$ 1.09 ^a
a	5.69 $\pm$ 0.46 ^c	6.04 $\pm$ 0.76 ^c	7.34 $\pm$ 0.60 ^b	8.93 $\pm$ 0.49 ^a
b	19.14 $\pm$ 0.24 ^b	19.23 $\pm$ 1.41 ^b	19.94 $\pm$ 0.96 ^{ab}	20.68 $\pm$ 0.53 ^a

Mean values with common superscript in a row are not differed significantly. *WHC* water holding capacity; *TFR* total fluid release; *FR* fat release; *WR* water release

The surface-active protein is adsorbed at the interface between oil and aqueous phase which reduces interfacial tension and prevent the oil droplets from coming close enough to aggregate (Paraskevopoulou et al. 2007). Moreover, under certain conditions such as protein-to-polysaccharide ratio, pH, ionic strength and temperature, the proteins and polysaccharides could undergo complex formation, which possesses better functional properties in comparison to the proteins and polysaccharides acting alone (Benichou et al. 2002). The improvement in the emulsion stability and activity has been attributed to the unfolding of the protein at the interface that enhances protein–polysaccharide interactions by exposing the cationic and hydrophobic groups of the protein.

Cooking loss between treated and control samples differed significantly ($P<0.05$) and was observed less in FSP treated samples probably due to its ability of keep the moisture in the matrix. However within various FSP treatments it was nonsignificant which might be due to the fact that the meat matrix with FSP which was stabilized more at 70 °C was somewhat destroyed at 100 °C, resulting in loss of unbound water and other nutrients during heat processing.

Incorporation of FSP significantly affected the color values of raw meat batters (Table 1). The values for lightness (L) and redness (+a) were decreased in treated as compared to control samples. This observed effect was linear i.e. incorporation of more FSP resulted in more decrease in L and a values. This was due to the fact that addition of FSP was associated with increase in the fat content and decrease in the myoglobin content which might result in lower redness values of FSP treated samples. However values for yellowness (+b) were not significant between treated samples whereas significant difference were observed when compared to control samples.

Sensory evaluation

Sensory scores for parameters such as appearance, flavor, texture, juiciness and overall acceptability were significantly affected ($P<0.05$) by the addition of FSP (Table 2). Generally, the highest sensory scores were recorded for the control samples except for juiciness scores which were significantly more at high FSP level. This is due to higher fat content, as fat in meat products plays important roles in product quality by stabilizing meat emulsion, reducing cooking loss, improving water holding capacity and providing juiciness (Carballo et al. 1995; Hughes et al. 1997; Pietrasik and Duda 2000; Yoo et al. 2007).

The sensory scores of cooked meat batter were decreased as the flaxseed content increased ($P<0.05$) and at 5 % FSP level product was moderately acceptable. Therefore, 5 % FSP level is considered optimum for use as an enhancer to the nutritive value in meat batter. Turhan et al. (2005) found that the overall acceptability scores of beef burgers decreased after more than 1–2 % hazelnut pellicle addition. On the contrary, Valencia et al. (2008) reported that sensory scores of pork sausages were not affected by the addition of linseed oil. The lower odor score for FSP treated samples might be due to the presence of polyunsaturated fatty acids which probably degraded during processing and gave paint or fishy odor in spite of fresh nutty smell. Due to this reason at higher FSP level odor score were observed lesser than the lower FSP level.

Texture profile analysis

The values for different attributes of texture profile of cooked meat batter stored under refrigeration are shown in Table 3.

Table 2 Effect of flaxseed powder (FSP) incorporation on sensory properties of cooked meat batter (mean $\pm$ SD) ($n=24$)

Parameters	FSP Level			
	5 %	2.5 %	1 %	Control
Appearance	6.69 $\pm$ 0.25 ^c	6.97 $\pm$ 0.32 ^b	7.25 $\pm$ 0.39 ^a	7.42 $\pm$ 0.46 ^a
Odor	6.67 $\pm$ 0.24 ^c	7.00 $\pm$ 0.34 ^b	7.33 $\pm$ 0.42 ^a	7.44 $\pm$ 0.45 ^a
Juiciness	7.58 $\pm$ 0.46 ^b	7.33 $\pm$ 0.42 ^b	7.03 $\pm$ 0.32 ^c	6.69 $\pm$ 0.25 ^d
Texture	6.69 $\pm$ 0.25 ^c	7.00 $\pm$ 0.34 ^b	7.33 $\pm$ 0.42 ^a	7.53 $\pm$ 0.47 ^a
Overall acceptability	6.67 $\pm$ 0.24 ^c	7.25 $\pm$ 0.39 ^b	7.42 $\pm$ 0.43 ^a	7.57 $\pm$ 0.41 ^a

Mean values with common superscript in a row are not differed significantly

The values were analyzed for treatment effect as well as for storage effect.

Lower hardness values were observed at more FSP levels, thus FSP incorporation decreased the hardness values of cooked meat batter. The values were increased continuously from day zero to day eight, indicating hardness were increased due to the effect of refrigerated storage. However increase in hardness values during storage was not more than that of increase in control samples thus stability of FSP treated samples was comparable to that of control samples. Springiness was observed more ($P<0.05$) in control samples than FSP treated samples. Except for one instance the values for springiness were decreased as FSP levels were increased between

treatments. Again like hardness these values were also increased as the storage days progressed and stability was somewhat similar to that of control samples. Cohesiveness at day zero, 4 and 6 was nonsignificant ($P<0.05$) but at day 2 and 8 was significant between different samples. An irregular trend was observed for cohesiveness values like at day 2 values were significantly more at 2.5 % FSP level than all other treatments including control samples while at day 8 values were significantly more at 1 % FSP level and control samples than other two treatment. Similarly, values for chewiness and gumminess differed significantly ($P<0.05$) among treatments. FSP incorporated samples had lower chewiness values than control samples. A linear trend was

Table 3 Effect of flaxseed powder (FSP) incorporation on texture properties of cooked meat batter during refrigerated storage (mean $\pm$ SD) ($n=9$)

Parameters	Storage period (Days)					
	FSP level	0	2	4	6	8
Hardness (N)	5	33.23 $\pm$ 1.28 ^{cd}	34.65 $\pm$ 0.93 ^{cd}	38.52 $\pm$ 2.24 ^{dc}	44.82 $\pm$ 1.40 ^{db}	47.15 $\pm$ 0.66 ^{da}
	2.5	34.21 $\pm$ 1.06 ^{cd}	35.97 $\pm$ 1.08 ^c	42.49 $\pm$ 1.08 ^{cb}	48.39 $\pm$ 1.20 ^{ca}	49.27 $\pm$ 0.61 ^{ca}
	1	38.43 $\pm$ 0.44 ^{bd}	42.62 $\pm$ 0.93 ^{bc}	47.1 $\pm$ 1.69 ^{bb}	53.73 $\pm$ 1.43 ^{ba}	53.21 $\pm$ 1.38 ^{ba}
	C	41.5 $\pm$ 0.81 ^{ad}	46.49 $\pm$ 0.63 ^{ac}	50.87 $\pm$ 1.59 ^{ab}	58.03 $\pm$ 1.36 ^{aa}	59.18 $\pm$ 0.64 ^{aa}
Springiness	5	0.70 $\pm$ 0.02 ^{ce}	0.73 $\pm$ 0.01 ^{cd}	0.78 $\pm$ 0.02 ^{cc}	0.82 $\pm$ 0.04 ^{bb}	0.86 $\pm$ 0.01 ^{da}
	2.5	0.73 $\pm$ 0.01 ^{bc}	0.74 $\pm$ 0.01 ^{bc}	0.82 $\pm$ 0.01 ^{ab}	0.84 $\pm$ 0.05 ^{ab}	0.92 $\pm$ 0.01 ^{ca}
	1	0.75 $\pm$ 0.02 ^{ad}	0.76 $\pm$ 0.02 ^{ab}	0.79 $\pm$ 0.02 ^{bc}	0.85 $\pm$ 0.02 ^{ab}	0.97 $\pm$ 0.04 ^{ba}
	C	0.76 $\pm$ 0.01 ^{ad}	0.77 $\pm$ 0.02 ^{ad}	0.81 $\pm$ 0.01 ^{ab}	0.87 $\pm$ 0.03 ^{ab}	1.00 $\pm$ 0.02 ^{aa}
Cohesiveness	5	0.63 $\pm$ 0.05 ^{AB}	0.62 $\pm$ 0.04 ^{AB}	0.64 $\pm$ 0.07 ^A	0.63 $\pm$ 0.06 ^{AB}	0.57 $\pm$ 0.01 ^{cb}
	2.5	0.66 $\pm$ 0.03 ^{AB}	0.70 $\pm$ 0.02 ^{AA}	0.65 $\pm$ 0.03 ^{AB}	0.60 $\pm$ 0.11 ^B	0.63 $\pm$ 0.07 ^{ba}
	1	0.62 $\pm$ 0.03 ^B	0.61 $\pm$ 0.01 ^{BC}	0.59 $\pm$ 0.03 ^C	0.61 $\pm$ 0.01 ^{BC}	0.72 $\pm$ 0.03 ^{aa}
	C	0.63 $\pm$ 0.02 ^B	0.62 $\pm$ 0.01 ^{BB}	0.64 $\pm$ 0.05 ^B	0.62 $\pm$ 0.04 ^B	0.69 $\pm$ 0.01 ^{aa}
Chewiness	5	14.50 $\pm$ 0.86 ^{dc}	15.63 $\pm$ 0.57 ^{dc}	18.96 $\pm$ 2.06 ^{cb}	22.87 $\pm$ 1.78 ^{ca}	22.77 $\pm$ 0.76 ^{da}
	2.5	16.40 $\pm$ 0.83 ^c	18.71 $\pm$ 0.86 ^c	22.45 $\pm$ 2.02 ^{bb}	24.51 $\pm$ 5.33 ^{bc}	28.62 $\pm$ 3.69 ^{ca}
	1	17.94 $\pm$ 0.58 ^{be}	19.87 $\pm$ 0.60 ^{bd}	21.81 $\pm$ 1.09 ^{bc}	28.17 $\pm$ 0.51 ^{ab}	36.71 $\pm$ 1.57 ^{ba}
	C	19.87 $\pm$ 0.24 ^{ae}	22.35 $\pm$ 0.85 ^{ad}	26.46 $\pm$ 2.19 ^{ac}	31.15 $\pm$ 2.46 ^{ab}	41.21 $\pm$ 1.70 ^{aa}
Gumminess	5	20.8 $\pm$ 0.97 ^{dc}	21.38 $\pm$ 1.02 ^c	24.46 $\pm$ 2.29 ^{cb}	28.11 $\pm$ 3.42 ^{ca}	26.48 $\pm$ 0.67 ^{da}
	2.5	22.57 $\pm$ 0.89 ^c	25.18 $\pm$ 1.13 ^{bc}	27.6 $\pm$ 2.09 ^{ba}	29.07 $\pm$ 5.19 ^{bc}	31.12 $\pm$ 3.50 ^{ca}
	1	24 $\pm$ 1.35 ^{be}	26.17 $\pm$ 0.72 ^{bd}	27.62 $\pm$ 1.18 ^{bc}	32.92 $\pm$ 0.09 ^{ab}	38.19 $\pm$ 1.05 ^{ba}
	C	26.32 $\pm$ 0.66 ^{ae}	28.84 $\pm$ 0.74 ^{ad}	32.65 $\pm$ 3.06 ^{ac}	35.7 $\pm$ 2.17 ^{ab}	40.87 $\pm$ 0.96 ^{aa}

Mean values with common small letter superscript (treatment effect) in a column for each parameter not differed significantly. Values with common capital letter superscript (storage effect) in row not differed significantly

Table 4 Effect of flaxseed powder (FSP) incorporation on surface and internal color values of cooked meat batter during refrigerated storage (mean $\pm$ SD) ($n=12$)

Parameters	Storage period (Days)					
	FSP level	0	2	4	6	8
Surface color						
L	5	64.03 $\pm$ 0.90 ^{dB}	66.68 $\pm$ 0.77 ^{cA}	66.85 $\pm$ 0.59 ^{dA}	66.58 $\pm$ 0.49 ^{dA}	67.26 $\pm$ 0.55 ^{dA}
	2.5	71.00 $\pm$ 0.91 ^{cC}	73.11 $\pm$ 0.98 ^{bB}	73.75 $\pm$ 0.54 ^{cAB}	74.22 $\pm$ 0.40 ^{cA}	73.94 $\pm$ 1.05 ^{cAB}
	1	73.18 $\pm$ 0.77 ^{bB}	75.89 $\pm$ 1.36 ^{aA}	76.16 $\pm$ 0.39 ^{bA}	76.39 $\pm$ 0.51 ^{bA}	76.65 $\pm$ 0.58 ^{bA}
	C	75.52 $\pm$ 1.39 ^{aB}	77.06 $\pm$ 1.39 ^{aA}	78.26 $\pm$ 0.32 ^{aA}	78.04 $\pm$ 0.50 ^{aA}	78.00 $\pm$ 0.38 ^{aA}
a	5	2.16 $\pm$ 0.30 ^{dB}	2.75 $\pm$ 0.39 ^{aA}	2.42 $\pm$ 0.21 ^{aA}	2.47 $\pm$ 0.18 ^{aA}	2.09 $\pm$ 0.10 ^{aC}
	2.5	2.47 $\pm$ 0.32 ^{cA}	1.30 $\pm$ 0.20 ^{cB}	1.07 $\pm$ 0.20 ^{cBC}	1.02 $\pm$ 0.21 ^{bC}	0.93 $\pm$ 0.16 ^{bC}
	1	2.67 $\pm$ 0.12 ^{bA}	1.14 $\pm$ 0.15 ^{cB}	0.97 $\pm$ 0.10 ^{cB}	0.94 $\pm$ 0.32 ^{bB}	0.62 $\pm$ 0.17 ^{cC}
	C	2.94 $\pm$ 0.22 ^{aA}	2.20 $\pm$ 0.12 ^{bB}	2.21 $\pm$ 0.14 ^{bB}	2.29 $\pm$ 0.22 ^{aB}	2.07 $\pm$ 0.17 ^{aB}
b	5	18.83 $\pm$ 0.68 ^A	16.46 $\pm$ 0.15 ^{bB}	15.64 $\pm$ 0.72 ^{bC}	15.60 $\pm$ 0.58 ^{bC}	15.18 $\pm$ 0.53 ^{bC}
	2.5	18.42 $\pm$ 0.72 ^A	13.20 $\pm$ 0.69 ^{dB}	12.87 $\pm$ 0.48 ^{cB}	13.10 $\pm$ 0.30 ^{cB}	12.75 $\pm$ 0.40 ^{cB}
	1	18.97 $\pm$ 0.57 ^A	15.47 $\pm$ 0.27 ^{cB}	14.90 $\pm$ 0.46 ^{bC}	15 $\pm$ 0.42 ^{bBC}	14.98 $\pm$ 0.33 ^{bBC}
	C	19.26 $\pm$ 0.52 ^A	17.84 $\pm$ 0.97 ^{aB}	16.97 $\pm$ 1.05 ^{aB}	17.06 $\pm$ 1.05 ^{aB}	16.92 $\pm$ 0.94 ^{aB}
Internal color						
L	5	70.29 $\pm$ 0.77 ^{cB}	71.70 $\pm$ 0.74 ^{dA}	71.87 $\pm$ 0.81 ^{dA}	72.35 $\pm$ 0.41 ^{dA}	72.23 $\pm$ 0.58 ^{dA}
	2.5	73.89 $\pm$ 1.43 ^{bB}	75.68 $\pm$ 0.05 ^{cA}	76.20 $\pm$ 0.11 ^{cA}	75.33 $\pm$ 0.91 ^{cA}	75.94 $\pm$ 0.34 ^{cA}
	1	77.76 $\pm$ 0.85 ^{aB}	77.97 $\pm$ 0.34 ^{bAB}	78.39 $\pm$ 0.40 ^{bA}	78.47 $\pm$ 0.10 ^{bA}	8.30 $\pm$ 0.28 ^{bAB}
	C	78.73 $\pm$ 0.90 ^{aB}	80.30 $\pm$ 0.18 ^{aA}	80.83 $\pm$ 0.19 ^{aA}	80.43 $\pm$ 0.26 ^{aA}	80.33 $\pm$ 0.30 ^{aA}
a	5	2.28 $\pm$ 0.07 ^{aA}	1.78 $\pm$ 0.14 ^{aB}	1.54 $\pm$ 0.08 ^{bCD}	1.67 $\pm$ 0.17 ^{bBC}	1.40 $\pm$ 0.13 ^{bD}
	2.5	1.70 $\pm$ 0.14 ^{dA}	1.49 $\pm$ 0.19 ^{bB}	1.31 $\pm$ 0.06 ^{cB}	1.36 $\pm$ 0.25 ^{cB}	1.07 $\pm$ 0.16 ^{cC}
	1	1.87 $\pm$ 0.06 ^{cA}	1.31 $\pm$ 0.03 ^{cB}	1.11 $\pm$ 0.27 ^{dC}	1.16 $\pm$ 0.12 ^{cBC}	0.69 $\pm$ 0.13 ^{cD}
	C	2.09 $\pm$ 0.15 ^{bA}	1.63 $\pm$ 0.09 ^{abC}	1.84 $\pm$ 0.16 ^{aB}	1.98 $\pm$ 0.12 ^{aB}	1.59 $\pm$ 0.16 ^{aC}
b	5	13.77 $\pm$ 0.69 ^{bA}	11.61 $\pm$ 0.32 ^{dB}	11.32 $\pm$ 0.25 ^{dB}	11.59 $\pm$ 0.19 ^{dB}	11.48 $\pm$ 0.20 ^{dB}
	2.5	13.70 $\pm$ 0.64 ^{bA}	12.53 $\pm$ 0.19 ^{cBC}	12.44 $\pm$ 0.20 ^{cBC}	12.87 $\pm$ 0.33 ^{cB}	12.34 $\pm$ 0.14 ^{cC}
	1	13.50 $\pm$ 0.31 ^{bA}	14.07 $\pm$ 0.16 ^{bB}	13.72 $\pm$ 0.12 ^{bC}	13.89 $\pm$ 0.08 ^{bBC}	13.67 $\pm$ 0.17 ^{bC}
	C	16.74 $\pm$ 0.43 ^{aA}	15.61 $\pm$ 0.35 ^{aB}	15.20 $\pm$ 0.28 ^{aC}	15.46 $\pm$ 0.11 ^{aBC}	15.53 $\pm$ 0.09 ^{aBC}

Mean values with common small letter superscript (treatment effect) in a column for each parameter not differed significantly. Values with common capital letter superscript (storage effect) in row not differed significantly

observed for effect of FSP level on chewiness and gumminess values. Similar to that of hardness and springiness, values for chewiness and gumminess were increased and differed significantly due to the effect of storage days. However stability of texture attributes was same as control samples indicating no negative effect in term of chewiness and gumminess values. Yılmaz and Dağlıoğlu (2003) indicated that meatballs made with the addition of oat fiber had characteristics similar to those of the present study. Yang et al. (2007) showed similar results when studying the effects of adding oatmeal and tofu to low-fat pork sausages.

Color properties

Different attributes of color determination like L, a and b values were significant ($P<0.05$) among different treatments due to the main effect of FSP level (Table 4). After cooking the L values were increased in all samples while a and b values

were decreased (Tables 1 and 2). Similar to raw samples lightness and redness values of cooked samples also observed

Fig. 1 TBARs (mg Malonaldehyde/kg) values (Mean $\pm$ SE) of treated and control meat batter during refrigerated (4 ± 1 °C) storage ($n=9$). FSP-flaxseed powder

more in control samples either measured at surface or internally hence FSP incorporation increased the darkness and decreased the redness of the product. However *b* values were decreased due to heat treatment (Tables 1 and 2) and values were nonsignificant between different FSP treated samples but significant when compared to control. The internal color values suggested that lightness was recorded more (internally) while redness and yellowness values were less as compared to surface values at day zero. The meat color changes from red to pink and grey-brown, and changes in color opacity occur during heat treatment. Martens et al. (1982) have observed that color opacity rises when the internal meat temperature is between 45 °C and 67 °C and assumed that the denaturing of the meat proteins myosin and actin, which do not contribute to the red color, overrides the red color of myoglobin. Eva (2005) has shown that the increase in meat color opacity is related to the denaturing of myosin, which starts at about 35 °C and at 40 °C, most of the original myosin molecules have changed to monomers with merged myosin heads. Above 50 °C, myosin molecules are completely coagulated and the meat appears opaque (Eva 2005). Also redness intensity in cooked meat is inversely related to the degree of denatured myoglobin, a denaturing process starting at 60 °C (Geileskey et al. 1998).

The lightness of surface increased as the storage days progressed in all samples and observed more ($P < 0.05$) in control samples at all analyzed points during storage. However redness and yellowness values of surface were decreased during storage. A measure observation after day 2 for surface and internal values among different treated and control samples were change in the redness pattern i.e. redness was observed in order 5 % > control > 2.5 % > 1 %. Thus data observed suggested that the color stability was somewhat similar in all samples. The difference in different values at different points were due to initial color values of raw and cooked samples which was due to main effect of FSP level between different treatments.

Oxidative stability

The thiobarbituric acid reactive substances as a measure of lipid oxidation differed significantly among treatments ($P < 0.05$) (Fig. 1). Higher TBARs values were observed at 5 % FSP level and lowest in control group at any stage of analysis. This is very obvious that the FSP contained more mono and polyunsaturated fatty acids which were more prone for primary and secondary oxidative degradation due to various mechanisms, hence more FSP treated samples showed more TBARs values. TBARs continuously increased from day zero to day eight in all the groups suggesting degradation of lipid during refrigerated storage. This is well established fact that mono and poly unsaturated fatty acids are very susceptible for free radical

attack and degraded in unpleasant odor forming compounds (Morrissey et al. 1998) during processing and storage (Wood et al. 2004). Results from other studies support that using olive and other vegetable for the manufacture of muscle foods enhances the oxidative instability of the final product (Choi et al. 2010; Kayaardı and Gök 2004).

Conclusion

Incorporation of functional ingredients in meat product formulation has great importance for development of health meat products; on the other hand with negotiating the product quality to an acceptable limit. This study revealed that incorporation of flaxseed powder upto 5 % did not alter most of the technological or physico-chemical properties of raw and cooked meat batter. In spite better results were obtained in FSP incorporated samples. However, the TBARs values, redness values and most sensory scores were lower in FSP incorporated samples which might be due to the high mono and polyunsaturated content of FSP. Thus, flaxseed powder could be added upto 5 % to enhance the nutritional value and health benefits of emulsion type meat products with minimal changes in sensory properties.

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