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Enrichment of wheat chips with omega-3 fatty acid by flaxseed addition: Textural and some physicochemical properties

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ABSTRACT

In the present study, wheat chips enriched with flaxseed flour were produced and response surface methodology was used for the studying the simultaneous effects of flaxseed level (10–20%), frying temperature (160–180 °C) and frying time (40–60 s) on some physicochemical, textural and sensorial properties and fatty acid composition of wheat chips. Ridge analysis was conducted to determine the optimum levels of processing variables. Predictive regression equations with adequate coefficients of determination ($R^2 \geqslant 0.705$) to explain the effect of processing variables were constructed. Addition of flaxseed flour increased the dry matter and protein content of samples and increase of frying temperature decreased the hardness values of wheat chips samples. Increment in flaxseed level provided an increase in unsaturated fatty acid content namely omega-3 fatty acids of wheat chips samples. Overall acceptability of chips increased with the increase of frying temperature. Ridge analysis showed that maximum taste score would be at flaxseed level = 10%, frying temperature = 180 °C and frying time = 50 s.

1. Introduction

Snack foods, particularly potato and corn chips, are commonly consumed by all ages of people groups all over the world (Thakur and Saxena, 2000). The efforts by snack food industry to develop new products to attract customers have increased in recent years. In addition, today's consumers demand foods with functional characteristics from industry due to the fact that people become more conscious toward what to eat (Melemma, 2003). The functional food provides positive impact on human health beside its nourishment property. These positive impacts can help to prevent or decrease the risk of heart diseases, cardiovascular problems, constipation, diabetes and so on (Hasler 2002; Koca & Anil, 2007). Wheat is a cereal which is grown in very high quantity in Turkey. Hence, Turkish people always eat wheat based products in their diet (Yüksel, Koyuncu, and Sayalsan, 2011). Wheat contains carbohydrates in high quantity therefore it is a good energy source for human nutrition. Wheat can be used easily for the production of wheat based chips products. The utilisation of wheat for the production of snack foods will enable people to consume wheat in a different form other than conventional products made from wheat such as bread and pasta (Rababah et al., 2011; Mendonça, Grossmann, and Verhe, 2000; Izydorczyk, Lagasse, Hatcher, Dexter, & Rossnagel, 2005).

Flaxseed belongs flax family and is known as *Linum usitatissimum.* Flaxseed contains 40–45% oil of which omega-3 is the major fatty acid. There are various studies in literature reporting the positive effects of omega fatty acids on human health (Yalçin and Ünal, 2010; Shearer & Davies, 2005). Because of the high unsaturated fatty acid content of flaxseed, fortification of foods with flaxseed can be good way to increase the omega type fatty acid content of the processed foods. With increasing consumption of flaxseed in nutrition, unsaturated fatty acid content of the human blood increases. Also flaxseed is a good source of fibre, vitamin and mineral and it is a food with functional properties to prevent or decrease the risk of cardiovascular diseases and cancer (Alpaslan & Hayta, 2006; Prasad, 2009).

The main aim of the present study was to enrich the wheat chips with flaxseed to produce a new snack food formulation for consumers and snack industry. Response surface methodology was used to determine the processing variables (flaxseed level, frying temperature and frying time) on the some physicochemical, textural and sensory properties of wheat chips and to optimise the formulation for the production of wheat chips enriched with flaxseed with high desirability and overall acceptability.

2. Material and methods

2.1. Materials

Wheat flour (14% moisture, 12% protein, 0.55% ash in dry matter) was obtained from Degirmencilik Flour Co., (Kayseri, Turkey).

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Flaxseed (7% moisture, 28% total dietary fibre (26% soluble fibre), 39% oil, 21.4% protein) and sunflower oil used for the frying (Kristal, İzmir, Turkey) were purchased from a local market in Kayseri (Turkey).

2.2. Methods

2.2.1. Preparation of chips

Fig. S1 (see Supplementary information) illustrates the process flow chart of wheat chips enriched with flaxseed. At first, dry mixtures containing wheat flour and flaxseed at different proportions were prepared (90:10, 85:15; 80:20). After homogenisation of dry mixture using dough mixer (Kitchen Aid Professional 600, MI, USA) for 5 min, 50 ml tap water was incorporated into the mix and it was kneaded for 10 min. At the end of the kneading, the dough was covered with a stretch wrap to prevent drying of dough and rested for 30 min at room conditions for proper hydration. Afterwards, the thickness of dough was adjusted to 1 mm using a lab-scale sheeter (Rondo, Doge, Model: SS0615, Switzerland) and the spreaded dough was moulded. Finally, chips were deep fried using a temperature controlled fryer (Philips Cucina, HD 6155, China). Different frying temperature (160, 170 and 180 °C) and frying times (40, 50 and 60 s) were selected as presented in the Table S1 (see Supplementary information) for the optimisation of processing variables. Fried chips samples were cooled on paper napkin at ambient conditions.

2.2.2. Proximate composition of wheat chips samples

Dry matter, protein, oil and ash contents of the samples were assayed according to the official procedures (AOAC, 2000). Dry matter content of the samples was determined by drying of samples at 105 °C for 4 h in a drying oven (Nüve FN 120, Ankara, Turkey). Ash content was determined by incinerating the samples at 550 °C for 6 h. The colour values of samples which were measured using a colorimeter (Lovibond RT Series Reflectance Tintometer, England) were recorded as L (brightness), a (±red–green) and b (±yellow–blue). Soxhlet extraction procedure was used for the determination of oil content of chips. Protein content of the samples was determined using automatic nitrogen analyzer (FP 528 Leco, USA) based on Dumas method.

2.2.3. Fatty acid composition of samples

The first step of fatty acid analysis is methylation of fatty acids. For this aim, 100 mg of oil sample extracted from fried chips sample was dissolved with 3 ml hexane and it was saponified with 100 μL 2 mol/L KOH (prepared with methanol). The mixture was vigorously shaken with a vortex (Nüve NM 110, Turkey) for 1 min, and then it was centrifuged at 2516*g* for 5 min at 25 °C (Hettich Rotina 380, Tuttlingen, Germany). 1 ml solution was put into vials and injection was started immediately into Gas Chromatography (GC) system (Agilent 6890, Ar., USA), equipped with a Flame ionisation Detector and HP-88 column (100 m × 0.25 mm ID). Injection block temperature was set at 250 °C. The oven temperature was kept at 103 °C for 1 min, then ramped from 103 to 170 °C at 6.5 °C/min, from 170 to 215 °C at 2.75 °C/min, finally held at 230 °C for 5 min. Helium was used as carrier gas with a flow rate of 2 ml/min and split rate was 1/50. Two replications were conducted for determination of fatty acid composition of oil samples. Fatty acid levels were expressed as "%" in total triglyceride.

2.2.4. Textural analysis

Wheat chips samples were subjected to the textural analysis with six replicates at room temperature using Texture Analyzer (TA.XT Plus, Stable Micro System Ltd., Surrey, England) equipped with a Kramer shear cell attachment (HDP/KS-5) using a 30 kg of load cell for the analysis. Two pieces of wheat chips (each approximately 3 g) were inserted in the Kramer shear cell. To ensure maximum number of blades contacting to the wheat chips, samples were placed as vertical to the Kramer shear blades. The blades travelled at 5 cm/min. The fracture force (*g*) which is the maximum force required to break the sample was determined from the time-deformation curve.

2.2.5. Sensory analysis

Wheat chips enriched with flaxseed were served to trained panel consisting of 10 members (faculty and graduate students of Erciyes University, Food Engineering Department) for sensory evaluation. Panelists cleansed their palates by deionised water prior to proceeding the next sample. Wheat chips enriched with flaxseed were evaluated using a scaling method of descriptive attributes for taste (1 = undesired, 7 = desired), colour (1 = very brown, 7 = desired yellowness), crispness (1 = undesired texture, 7 = desired texture) and overall acceptability (1 = dislike, 7 = like).

2.2.6. Data analysis and modeling

A 3-factor-3 level Box Behnken experimental design (Box & Behnken, 1960) with three replicates at the center point was used for the modeling of processing variables (flaxseed level, frying temperature and frying time) and predictive regression models were constructed for the analysis parameters. As stated before, the three processing variables (factors), levels and experimental design regarding to coded and uncoded values are tabulated in Table S1 (see Supplementary information). Second-order polynomial equation of function X_i as stated below was fitted for each response analysed:

$$Y = b_0 + \sum_{i=1}^{3} b_i X_i + \sum_{i=1}^{3} b_{ii} X_{ii}^2 + \sum_{i=1,\ i<j}^{3} \sum_{j=1}^{3} b_{ij} X_i X_j$$

where Y is the estimated response; b_0, b_i,b_{ii}, b_{ij} are constants. X_i, X_{ii} and X_j are processing variables (flaxseed level, frying temperature and frying time). Uncoded values were used for performing analysis. The number of tests for the Box–Behnken design could be limited to 15 as seen in Table S1 (see Supplementary information). The experimental combinations were carried out in triplicate (6th, 13th and 14th runs as indicated in Table S1 (see Supplementary information)) in the center point of the model for the estimation of the experimental variance. The response surface analysis was performed using JMP statistical package software (Version 5.0.1.a SAS Institute. Inc., Cary, NC, USA) and Statistica for Windows (Version 8.0 Statsoft Inc., OK, USA) was used for the computational work including 3D surface plots. Estimated ridges of maximum and minimum response for increment radii from the center of the original design were determined.

3. Results and discussion

3.1. Physicochemical properties of wheat chips enriched with flaxseed

Physicochemical analysis results of wheat chips enriched with flaxseed were tabulated in Table S2 (see Supplementary information). Box–Behnken design was used to show the main effects of processing variables (flaxseed level, frying temperature and frying time) and their interactions. Limits of processing variables were determined after preliminary studies. The dry matter content of samples increased significantly with increasing of flaxseed concentration ($p < 0.05$, Table 1). The highest dry matter content was determined in the samples containing 20% flaxseed and fried at 180 °C for 50 s while the lowest was in the sample containing 10% flaxseed and fried at 170 °C for 40 s. Frying temperature and time caused a significant effect on the dry matter content of the final wheat chips. As can be seen in the Fig. 1b, increment in frying