Effects of Addition Lentil Flour on the Batter Formulation on Quality of Simulated Fried Crust by Using a Deep-Fried Model System

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Abstract— **In this study, the influences of frying time and lentil flour addition to the batter formulation on the quality of simulated crispy deep-fried crusts was investigated by using a deep-fried crust model. To determine the effects of lentil flour, different concentration of lentil flour (10%, 25% and 50% w/w) was replaced with wheat flour. Control batter formulation contained only wheat flour. Moisture content, oil content, color and hardness of the samples were determined. Crust models were fried at 160°C and 180°C for 90, 180, 270 and 360 s. Batter formulations and frying time significantly (p < 0.05) affected moisture content, oil content and color of Crust models. Batter formulation and frying time significantly (p<0.05) affected moisture and oil content of crusts. Substitution of different concentration of lentil flours to the batter formulation decreased the oil content of the final product. 50% lentil flour substituted was found to be an effective formulation in decreasing oil content of fried crusts in all of the times. Control sample showed the lowest moisture content and highest oil content among all the formulations. The mean moisture and fat content of fried crusts contained 50% lentil flour substitution and control, fried at 180 °C, for 6 min were 0.217±0.087, 0.006±0.003, and 0.215±0.005, 0.248±0.004, (g/g db), respectively. By increasing substitution of lentil flour in batter formulation, color was darker.**

Keywords- **Frying; Deep-Fried Crust Model System; lentil flour; reducing oil content**

I. INTRODUCTION

In recent decades, as the result of industrial life, consuming fried and fast foods have increased significantly. Excessive use of fat, especially saturated fats and trans fatty acids is one of the important factors that increases heart diseases, weight gain, and cancers (1,2). With increasing consumer awareness of the effect of dietary fat on health, tendency to produce and consume low-fat foods is increasing significantly. Therefore, using effective methods for decreasing fat absorption not only retains desirable features but also seems essential.

Deed fat frying is one of the common methods for preparing foods. In this process, food is fried by immersing in edible oil in a temperature between 150 to 200 °c. (3,4) Quick and easy preparation, desirable sensory features like colour, texture, appropriate taste and smell in fried foods increase the desirability of these materials. However, such foods contain high amount of fat (5, 6, 7, 8) Because of consumers' increased awareness of the relationship between health and nutrition, tendency to consume low-fat foods is increasing (8). One of the methods which is used for decreasing fat absorption during frying process is changing the batter formulation. The batter's ingredients and even the constituents in the flour affect batter's characteristics (9). So batters are sophisticated systems in which the functionality of the ingredients, their composition, concentration, and characteristics determines all the final quality performance of the coated foods (10). Combination or replacement of wheat flour with some another type of flour is done for the purpose of improving the rheological properties of the batter and its effective on moisture removal and fat absorption with an improvement of product nutrient due to amino acid combinations and different minerals The effect of different flours made from different cereals has been studied in fried batter systems (11, 12, 13, 6, 14; 15, 16). Dehghan nasiri et al, investigated the effect of adding soy flour (10 percent of weight/weight) and corn flour (5 percent of weight/weight) to batter formulation of fried shrimp batter. Results of the study indicated that soy flour and corn flour significantly decreases fat absorption of shrimp nugget (16). Lee & Anglet adding barely flour to batter formulation increases its absorption and viscosity, and leads to a significant decrease in moisture removal and fat absorption in fried products (14). Dogan et al, also reported that adding soy flour to the formulation of chicken nugget batter decreases fat absorption (6). On the other hand, characteristics of the frying products crust has a significant role in the amount of the mass and energy transfer during frying and also in qualitative features and product acceptance. However, there is not much information about the effect of legumes flour on formulation of batter. Absorbed oil in fried products usually has a tendency to be absorbed in the pores of crust. Lack of similar cores and its characteristics has led to a decrease in repeatable possibility of production. To solve these problems, crust model system can be useful during frying (DFCM) for quick making of fried crust (17). Their results indicated that produced crust using crust model has a desirable correlation in fat absorption content and moisture content with the sample in the experiment.

Therefore, the purpose of the present study is to study the effect of different batter formulations (replacing different levels of lentil flour with wheat flour) on qualitative characteristics of produced crust using DFCM method.

2. Materials and Methods

2.1. Batter Preparation

Wheat flour was purchased from local market to prepare the batter. Lentil flour was obtained from Shirvan Agricultural Research Center, Shirvan, Iran. The solid content of batter formulations contained wheat flour, salt, leavening agents, and flavor (pepper). To determine the effects of lentil flour on the quality properties of simulated crispy deep-fried crusts, 10%, 25% and 50% of wheat flour was replaced with lentil flour. As a control, a batter with wheat flour was used. The characteristics of the flour samples are presented in Table 1. The thoroughly pre-blended powders were mixed with cold water (15 °C) with a mixer (Moulinex, type BM4) for 2 min to ensure uniform mixing. The water/dry mix proportion was always 1.2:1 (w/w).

2.2. Crust Model Preparation

Deep-fried crusts were prepared using a model system [18, 17]. Batters were deep-fried using a stainless steel device that holds two aluminum cups (64 mm diameter, 28 mL volume). Each cup was covered by gauze with a mesh diameter of 0.18 mm and a wire diameter of 0.14 mm. The gauze was coated with Teflon to prevent the crust from caking to the gauze during frying, in which 2 samples can be fried simultaneously. Each crust model was prepared by depositing first 4 mL of batter on Teflon coated gauze that was placed above a cup containing 5 g of silica gel. The presence of a core is essential to simulate the crust formation of a real product. Water evaporating from the core during frying plays an important role in crust formation. This vapor will have an effect on crust temperature. Conditioned silica powder provided an ideal core, moisture content was easily adjusted, and properties of the powder were highly reproducible. Silica is inert, thus, apart from the moisture evaporating, no other reactions are taking place during frying. The moisture content of the silica powder was set by storing the powder on a flat surface in a germinator (Altus 400-Iran, 375litet) to simulate the wet core characteristic of deep-fried battered samples (moisture content is almost 85%), in 22°C for at least two days. Crust models were prepared by frying in refined sunflower oil (Nina, Iran) due to its high smoking point, in a thermostatically temperature controlled fryer (Black & Decker, Type 01) for 90, 180, 270 and 360 seconds at 180°C. Crust models were separated from the gauze. After frying, the crusts could be separated easily from the gauze for further analysis. All examinations of the crust models were measured 30 min after frying.

2.3. Moisture Content Analysis

For moisture determination, the crust model samples were dried in a conventional oven (Memmert, 154 Beschickung loading, model 100 - 800) at 105°C up to the establishment of constant weight (19). Moisture contents were determined by difference in weight in terms of dry basis.

2.4. Fat Extraction

The oil content of the fried samples was determined by using Soxhlet extraction method with petroleum ether (Extra pure, ET0091) for 6 h (20). The thimbles were further dried at 105°C for 60 min to remove residue solvent and moisture. Then the thimbles were cooled in a desicator and subsequently weighed. The oil contents were obtained in terms of dry basis.

2.5. Color

Color of crust models was measured using an image processing technique as following:

1) A computer vision system generally consists of four basic components: illumination, a camera, computer hardware, and software. In this research, sample illumination was achieved with four fluorescent lights (Opple, 8 W, model: MX396-Y82, 60 cm in length) with a color index (R_a) close to 95%. The illuminating lights were placed in a wooden box, 45 cm above the sample and at the angle of 45° with sample plane to give a uniform light intensity over the crust models .The interior walls of the wooden box were painted black to minimize background light. So that stabilization the lighting system, it was switched on for about 30 min prior to acquiring images. A color digital camera (Canon EOS 1000D, Taiwan) with lens focal length 35 mm was located vertically at a distance of 25 cm from the sample. The angle between the camera lens axis and lightening sources was around 45°. The iris was operated in manual mode, with the lens aperture of 4, ISO 200 and speed 1/80 s (no zoom, no flash) to achieve high uniformity and repeatability. Images were captured with the mentioned digital camera at 2592 × 3888 pixels and connected to the USB port of a computer. Canon Digital Camera Solution Software (Canon Utilities Zoom Browser EX Version 6.1.1) was used to acquire the images in the computer in JPEG format.

2) Image preprocessing: Improvement of background's contrast of images and segmentation (to separate the true images of the bell peppers from background) was performed using Adobe Photoshop (Adobe, v.8.0).

3) Alteration of RGB chromatic space into L*a*b* units: Since the L*a*b* color is device independent and providing consistent color regardless of the input or output, the images taken were converted into L*a*b* units [21]. In this study, the image analysis was managed using ImageJ software (National Institutes Health, Bethesda, Md, USA) version 1.40 g.

2.6. Statistical Analysis

All experiments were performed at least two times each experimental condition and mean values were reported. Data obtained from analysis were assessed by ANOVA (Analysis of Variance) by SPSS 14.0 (SPSS Inc.) to determine the significant differences between the effects of frying time and lentil flour substitution on quality parameters of the crust models. When significant differences were found, the Duncan's multiple comparison tests were applied to determine the difference among means ($p \leq 0.05$).

3. Results and Discussion

3.1. Moisture Content

The effect of frying time and batter formulation were significantly effective ($p<0.05$) in controlling moisture loss during deep fat frying (Figure 1). The moisture content in all formulation was found to decrease with frying time due to further frying and heating. Addition of lentil flour had a significant effect on the moisture content of crust models, as it is shown in Figure 1; the highest moisture retention in each frying time was reported when 50% lentil flour was added in the batter formulation which might be due to its higher water binding capacity (6). Also, it could be due to the potential formation of intermolecular disulfide cross-links in lentil proteins that improved the barrier properties of the lentil flour added batter for water vapor. Wheat flour had less water-binding capacity as compared to lentil flour; therefore, there was more free water available to facilitate the evaporation of water during deep fat frying and control crust lost the highest amount of water during frying. Furthermore, there is an initial rapid fall of moisture content in the first minute of frying mainly due to loss of surface water. Similar pattern was reported by other authors (22, 23, 16).

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Table 1. Chemical composition of wheat, soy, and corn flours used in the study

Flour type	Wheat flour	Wheat flour
Moisture (%)	11.67	10.52
Protein (%)	10.13	31.02
Ash (%)	0.96	1.48
Crude fat	3.12	5.43

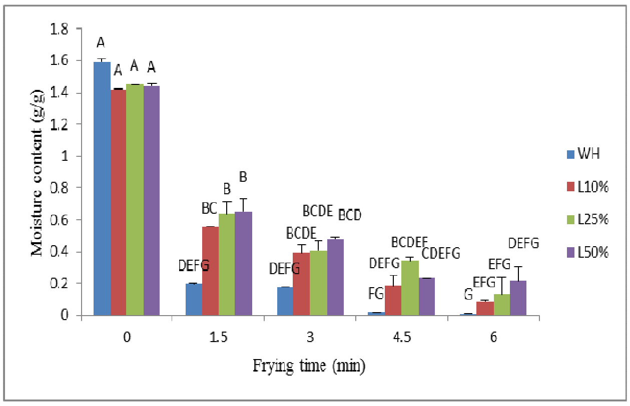

Figure1. Effect of frying time and formulation on moisture content of DFCMs at 180°C

3.2. Fat Content

Oil uptake was found to increase with increasing frying time (Fig. 2). This could be attributed to the formation of porous. While the temperature of the interior food increases, it cause water evaporation and form pores on the crust during frying. Therefore, oil diffuses to the porous crust leading to higher oil content and lower moisture content in the crusts of fried foods (10, 17). Moisture content is an important factor in determining oil uptake during deep fat frying. Water evaporation creates cavities during frying. These capillary pores work as pathways in the food and subsequently filled by oil [22]. There was an opposite relationship between moisture loss and oil uptake, so higher oil content corresponded with lower moisture content [22, 24, 25]. The addition of lentil flour to the batter formulation reduced oil absorption significantly during frying when compared with the control (Fig. 2). The final fried control had less moisture contents (4–8%) and higher oil contents (28.2–28.7%) and the crusts containing 50% lentil flour had higher moisture contents (20.6–21.7%) and lower oil contents (21.6%) Less oil absorption of crusts containing 50% lentil flour related to higher protein content and higher water-binding capacity of lentil flour (16, 6). Furthermore, it may be related to the formation of covalent links during heating. The reduced oil uptake may also be related to thermal gelation and the film-forming ability of lentil protein.

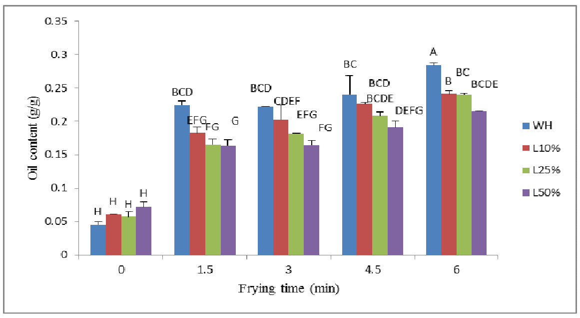

Figure 2.Effect of frying time and formulation on fat content of DFCMs at 180°C.

3.3. Color

The effect of lentil flour on the color of deep-fat fried crust model was examined in terms of L*, a* and b* values. As frying time increased, the lightness (L*) of the crust models decreased, While redness (a*) and yellowness (b*) increased significantly with frying time. The color of deep-fat fried chicken nuggets was studied by Dogan et al., they found that as frying time increased, L* values decreased and the a* value increased [6]. Control sample had lighter-colored crusts. By increasing substitution of lentil flour in batter formulation color was darker (Table 3). This could be related to the higher amount of protein in lentil flour undergoing Maillard reactions. Also, when lentil flour content in coating solutions increased, the brownish color increased in coated samples. These may be due to browning reaction of polysaccharide with protein complex when it was heated at high temperature (26).

III. CONCLUSION

The influences of frying time and lentil flour addition to the batter formulation on quality properties of DFCMs were investigated. The results showed that It is advantageous to add lentil flour to the wheat flour based batter formulation in order to reduce oil content of DFCM. When all of the quality parameters were considered, lentil flour added batters increased the crispness, improved the color and decreased the oil content of DFCMs. Therefore, replacement of a small portion of wheat flour with lentil flour can be recommended to be used in batters for nuggets.

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Table 2.Analysis of variance results (mean squares values)

Source	d.f.	Moisture content (g/g)	Fat content (g/g)	b*	a*	L*
Frying time	4	2.420**	0.0409**	794.33**	217.88**	457.08**
Formulation	3	0.091**	0.0032**	187.73**	2.63 NS	31.02**
Frying time × Formulation	12	0.024**	0.0005**	3.66*	3.00 NS	1.29NS
Error	20	0.006	0.0000	0.81	2.72	5.43
Total	39					

NS= not significant, **p=0.01, *p=0.05

Table 1. Effects of frying time and formulation on color parameters of DFCMs at 180°C.

Formulation	Frying time	L*	b*	a*
WH	0	94.02±0.62^{A}	19.80±0.09^{G}	-9.20±0.13^{GH}
WH	1.5	84.27±0.70^{BCD}	43.50±0.22^{D}	-6.40±0.23^{EFGH}
WH	3	82.86±0.30^{CDEF}	43.82±1.07^{D}	-5.53±0.38^{EFGH}
WH	4.5	81.12±0.17^{DEF}	45.04±0.32^{D}	-3. 54±0.19^{CDEFG}
WH	6	73.96±0.53^{EFG}	46.07±0.98^{D}	1.22±0.85^{ABCD}
L10%	0	93.09±0.55^{AB}	27.57±0.12^{F}	-9.36±0.21^{GH}
L10%	1.5	84.99±0.48^{ABCD}	46.95±0.04^{CD}	-7.52±0.39^{FGH}
L10%	3	82.12±0.68^{CDEF}	50.81±1.01^{B}	-4.88±0.42^{DEFGH}
L10%	4.5	77.68±0.23^{DEFG}	52.60±1.03^{AB}	-0.14±0.29^{ABCDE}
L10%	6	73.49±0.37^{FG}	52.89±0.33^{AB}	3.00±0.23^{ABC}
L25%	0	90.88±0.91^{ABC}	32.79±0.13^{E}	-10.66±0.09^{H}
L25%	1.5	81.79±0.07^{CDEF}	51.21±1.27^{B}	-9.47±0.22^{GH}
L25%	3	79.58±2.33^{DEF}	53.08±0.78^{AB}	-6.08±0.71^{EFGH}
L25%	4.5	76.67±2.82^{DEFG}	53.10±1.39^{AB}	-2.38±1.41^{BCDEF}
L25%	6	68.99±0.03^{G}	53.73±1.54^{AB}	4.89±0.01^{A}
L50%	0	90.86±0.87^{ABC}	32.80±0.16^{E}	-10.66±0.09^{H}
L50%	1.5	83.06±2. 48^{CDE}	50.10±1.57^{BC}	-9.07±0.99^{GH}
L50%	3	79.55±2.33^{DEF}	53.04±0.74^{AB}	-6.08±0.73^{EFGH}
L50%	4.5	76.64±2.80^{DEFG}	53.07±1.43^{AB}	-2.38±1.38^{BCDEF}
L50%	6	70.04±1.09^{G}	55.32±0.18^{A}	3.56±1.45^{AB}