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Development of low-fat chicken nuggets using fish protein concentrate in batter formulation

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Abstract

The effect of various levels (5, 10 and 15%) of fish protein concentrate (FPC) in batter formulation was investigated. The physicochemical properties of chicken nugget were evaluated in order to find the optimium level of FPC in batter formulation. Flow behavior showed that the control batter and a treatment contains of 7.5% FPC had higher viscosity. Moisture loss and fat uptake in control sample was higher than all treatments contain FPC in both deep fat and air fryer. Thicker crust resulted by higher level of FPC in batter leads less oil uptake during frying. Moreover, the samples contain FPC had the highest score in terms of texture and overall acceptability. In spite the fact that nuggets contain FPC had the high rate of our research priorities, however, the level around 15% considered as a limitation. Using desirability optimization, the range between 7.5- 8% of PFC in batter formulation was selected as the best level.

Keywords: Chicken nugget, Desirability, Fat absorption reduction, FPC, Frying

Introduction

Chicken nugget is the most popular restructured meat and a popular snack prepared using chicken meat which is consumed by adults and children as their favorite meal (Evanuarini and Purnomo 2011). However, healthy food is the most important priority for consumers and chicken nugget as a fried food with high calorie content is highly health concerns. Hence, nowadays many studies focus on the fat reduction in fried food (Adedeji, 2010; Mah, 2008).

Some factors like frying time and temperature, initial moisture content, post frying treatment and surface condition of food influence on fat absorption in frying (Rice and Gamble 1989; Gamble and Rice 1988; Adel-aal and Karara 1986; Fan and Arce 1986; Mittelman *et al.,* 1982; Pinthus and Saguy 1994; Lulai and Orr 1979; Ng *et al.,* 1957). In addition, surface properties act as a determining factor in the level of fat absorption and moisture loss. Batter described as a different level of flour to water mixture which food items are dipped inbefore frying (Loewe, 1990). Applying edible coating and batter system are considered as a convincing method to surface modification and fat uptake reduction (Adedeji and Ngadi, 2009; Pedreschi *et al.,* 2005; Mellema, 2003; Mallikarjunan *et al*., 1997).

Great emphasis on reduction in dietary fat intake to less than 30% of calories is suggested by health organizations (Saguy and Pinthus, 1995) and consumer demand for low fat fried food with good organoleptic attributes (Gennadios, 2002) encouraged researchers towards methods of oil absorption reduction with no adverse effect on other quality attributes such as taste, texture, and surface color during deep fat frying (Hansen, 1998). According to many researches, protein-based edible films and coatings proved to be a proper alternative for aforementioned issues. In other word, they can form structures and networks and contribute in improvement the food quality properties by interacting with other components (Kinsella *et al.,* 1994). The three-dimensional network formation enables proteins to

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physically entrap a large amount of water within the matrix (Hermansson, 1979). Furthermore, they possess hydrophilic properties and exhibit the ability of lipid barrier, a barrier between foods and frying medium (Krochta and De Mulder-Johnston, 1997), reduced moisture migration, improve breading adhesion, increased retention of natural juices and flavors and enhanced texture and appearance. So, in some cases protein can replace with the main part of the batter system, flour, to reach the aim.

On the other hand, in spite of the same nutritional value, some of the fish species are less favorable. In fact, they have no commercial value and the reasons ley behind it; can be an unusual size and unappealing taste. Hence, only a few fish species are usually consumed which cause fish consumption to be restricted to people of the specific level. But, nowadays the general view changes toward utilization of fish protein products in their meal. These are low cost and high quality, these can fill protein gap especially among poor people and diminish protein deficiency (Cordova-Murueta *et al.*, 2007). Furthermore, FAO (2006) reported that fish protein concentrates in human diet especially sustainable growing babies and pregnants is beneficial and improve the quality of life. It is also noted that fish by-products are able to reduce blood pressure, type-II diabetes (McCarty, 2003), improve glucose tolerance and insulin sensitivity (Lavigne *et al.*, 2000) when using as protein supplements in food products. Fish by-products can considered as an intermediate product and gain commercialization. In another word, they can be processed to a high quality and applicable fish products which can be utilized in human consumption as an ingredient in different food product formulations (Martin, 2012). Hence, using low-cost fishes is becoming increasingly important, as they can be converted to fish protein concentrate or fish protein hydrolyzate. It is possible to increase protein concentration by removing water, oil, bones and other materials (Finch, 1977). Based on this definition, Finch (1977) and Mackie (1983) stated that the FPC can be produced by the simple removal of water from fish flesh.

Besides all the sbove mentioned, functional properties are the considerable factor if the protein is utilized as an additive in food products. So the aim of this research is discovering the functional properties of FPC and its optimium level as an ingredient in batter formulations. Furthermore, to reach the low fat fried food with good organoleptic attributes, oil absorption reduction with no adverse effect on other quality attributes during deep fat frying, on the other hand the low cost and high quality of fish by- products were the motivation and sufficient reason of utilization fish protein concentrate in the batter system of chicken nugget and evaluation of product.

Materials and methods

Fish protein concentrate

Food-grade FPC from Saithe (Pollachius virens) was purchased from national marine research institute of Anzali prepared under sanitary conditions. According to Knobl et al. (1971) the procedure contains of two consecutive sets of step in which fish and isopropyl alcohol were mixed, then the solid and liquid were separated in a centrifuge. The final solid phase was de-solventized in a vacuum oven at 160˚C for about 18 to 22 h.

Physicochemical analysis of FPC

Fat, moisture, crude protein and ash of fish protein concentrate were determined by standard procedures of Association of Official Analytical Chemists (1990). Crude protein content was determined using the Kjeldahl method (Kjeltec System, FOSS Tectator, Hoganas, Sweden). Crude lipid content was measured by the Soxhlet method (Soxtec System-Texator, Sweden). Ash content was determined by ashing samples about 5 hours at 550°C. Moisture content was determined by drying samples for 4 h at 105°C until constant weight was achieved. Carbohydrate content was calculated by difference. The pH of the FPC samples was measured according to Bragadottir et al. (2007).

Functional properties

Solubility

Solubility was determined based on the Eastman and Moore method (1984) with some modification. One g of powder was added to 100 ml of distilled water and mixed at high velocity in a mixer for 5 min. The solution was centrifuged for 5 min at 30.000× g. then 25 ml of the supernatant was oven-dried at 105ºC, for 5 h in a weighed Petri dishes. Weight difference of petri dishes before and after oven-drying described solubility (%).

Water holding capacity

The water holding capacity was measured using the method described by Taheri et al. (2013), FPC and distilled water in a ratio of 1 to 10 were mixed and centrifuged for 20 min at 1800×g. The difference between primarily volume of water and the supernatant determined as a milliliter of water absorbed per gram of protein.

Oil binding capacity

According to Taheri et al. (2013) a ratio of 1/10 FPC to sunflower oil was vortexed for 30 sec, let the mixture remains in a room temperature for 30 min. Then it was centrifuged for 10 min at 13600× g. The oil on the top was pulled and gram of the oil absorbed expressed as the oil binding capacity.

Batter and chicken nugget preparation:

The nugget core formulation was prepared by mixing %86 boneless and skinless chicken breast, %12.9 onion, %1 salt and %0.1 pepper in a mixer then shaped in 2.8*2.8 dimensions. Batter was prepared by mixing %90.8 wheat flour, %3.1 baking powder, %0.6 pepper, %5.5 salt w/w and a portion of 1.2 water to dry mix. In order to investigate the effect of FPC in batter formulation, wheat flour was replaced with 5, 10 and 15% FPC. Chicken samples were dipped in batter then fried in a deep fat (containing 1.5 litter sun flower oil at 170 ℃ for 8 min) and air fryer (170°C for 28 min). It should be noted, the time and temperature in each fryer determined based on pre-treatment test and according to device instruction. Fried nuggets were allowed to remove their excess oil on a tissue paper before consequent analysis.

Batter rheological test

Batters flow behavior was determined using a Bohlin rotational viscometer (Bohlin, Visco 88, Bohlin Instruments, UK). Proper spindles (C14, C25 & C30) were selected based on samples viscosity. Shear rate logarithmic elevation occurred over the range 14.2– 200 s^{-1} at 25°C. Batters flow behavior (shear stress-shear) was described based on the power law model:

$$\tau = k\dot{\gamma}^{n} \tag{1}$$

Where τ is the shear stress (pa), g: is the shear rate (s^{-1}), k is the consistency coefficient ($Pa.s^{n}$), and n is the flow behavior index (dimensionless).

Chicken nugget analysis:

Moisture content and Fat content

The whole samples were placed in a conventional oven (Memmert) for 24 h at 105˚C according to AACC (1986). Samples were weighted to determine dry basic moisture content followed by cooling in a desiccator. Fat content analysis was carried out by soxhlet extraction using the dried sample used for moisture content determination (AOAC, 1990).

Crust thickness

A computer vision system consists of illuminating lights placed 45 cm above the sample in a wooden box was used for crust thickness evaluation. A color digital camera (Canon EOS 1000D, Taiwan) was located vertically. Samples were cut vertically and images were captured with the above digital camera. The crust thickness was measured using Image J software (National Institutes of Health, USA) version 1.42e. The distance between two lines in the picture measured by straight line tool in the software considered as a crust thickness (Fig 1).

Sensory properties

Ten regular consumers of nugget were invited to evaluate color intensity, texture, oiliness, internal moisture, flavor and overall acceptability using a 7-point hedonic scale. 1 represented extremely dislike and 7 extremely like. Evaluation was performed in a partitioned sensory laboratory, under the white fluorescent light, two sets of three digit coded samples were assessed and tap water was used between the samples consumption.

Fig. 1. The distance between two lines stands represent the crust thickness of nugget samples.

Statistical analysis and optimization

Data from randomized design were analyzed using analysis of variance. Treatments means were compared by Duncan's multiple range tests using SPSS 16.0 for Windows (SPSS Inc., Chicago, USA). Besides, multiple response method (desirability) was used in order to find optimized level of FPC based on physicochemical and sensorial characteristics.

Results and discussion

Physicochemical properties of FPC

The proximate composition of FPC used as a material for batter preparation is given in Table 1. Based on reports by Cordova-Murueta et al. (2007); Sathivel et al. (2009); Shaviklo et al. (2010a), fish species and added ingredients are the determinant factor of FPCs proximate composition. The protein content of FPC utilized in this research is mostly similar to freeze dried saithe protein isolate reported by Shaviklo et al. (2012); Barzana and Garcia-Garibay (1994). Also, Sen (2005) reported higher than 65% of protein content for FPC prototypes.

Table 1- Proximate composition

	Moisture	Fat	Protein	Ash	pH
FPC sample	4.15	0.5	94.25	1.1	6.78

Functionality

The functional properties of FPCs are depicted in Table (2). Drying process can affect physicochemical changes of protein and functional properties. So, based on different drying and processing conditions, no one can anticipate the same product from the same raw material (Shaviklo *et al*. 2010a, 2012).

FPC exhibited oil binding capacity of 1.97 g oil/g protein. According to He et al (2015), it can be concluded that the FPC with low oil-binding capacity can cause the fried food to absorb lower amount of oil. Water holding capacity of FPC is fairly similar to other products include freeze dried saithe protein isolate without additives, freeze dried Fish protein isolate with 5% sucrose and 0.2% phosphate, spray dried saithe with additives (2.5% sucrose and 0.2% phosphate), Freeze dried saithe without additives and Freeze dried saithe with additives (2.5% sucrose and 0.2% phosphate) which reported by Shaviklo et al. (2012) and Shaviklo et al. (2010c). Relatively high water holding capacity is attributed to high level of protein content of FPC. FPC protein solubility was higher than hake protein powder (HPP), soy protein concentrate (SPC) and pea protein isolate (Pires *et al*., 2012) however, it was lower than the egg white powder (Pires *et al.,* 2012) and Fish protein hydrolysates (Souissi *et al.,* 2007). The relatively low solubility of HPP and FPC may result from myofibrillar proteins solubility which is highly soluble at very acidic or alkaline pH and less soluble between 4.0 and 9.0 (Batista *et al*., 2006). Moreover, the distinction among several results can be attributed to the difference in peptide length and the ratio of hydrophilic/hydrophobic peptides (Souissi *et al.*, 2007).

Table 2- Functional properties

	Solubility	WHC	OBC
FPC	24.13%	305%	1.97goil/gpr

Batter rheology

Apparent viscosity of different batter formulation was investigated as a function of shear rate (Table 3). Non-Newtonian shear thinning behavior was the obvious feature of all formulations. The power law ($R^2 \geq 0.91$) was the best model for describing the experimental data. Batter contains 15% of FPC and the standard sample had the highest and lowest viscosity respectively which represented that increasing the FPC in the batter formulation causing an enhancement in a batter viscosity. Viscosity significantly influenced by composition and proportion of ingredients, the solids–water relationship, temperature, solubility and water binding capacities of the dry ingredients, molecular weight, and structural association (Meyers 1989; Baixauli *et al*., 2003; Fiszman and Salvador 2003). Fiszman and Salvador (2003) and Sahin and Sumnu (2009) claimed that the proteins in batter provide a structure and increase the consistency of raw batters which is reflected by a rise in viscosity. Dogan et al. (2005) asserted that characteristics of dry ingredients have a key role in a batter viscosity development. They also explained that the highest viscosity of batter contains of soy flour is related to the maximum amount of bonded water among different flour. Therefore, it can be concluded that the higher viscosity of batter contains of FPC, compare with the control can be explained by higher amount of water bonded by FPC. Control batter providing low viscosity may be due to more free water available for movement like Grape Seed Powder- added batter in Kumcuoglu et al (2015). Batter viscosity influence on final product appearance, texture and oil uptake.

Table 3- Consistency index (K) and flow behavior index (n) of batter with different level of FPC

	K (Pa S^n)	n	R^2
Control	47.08	0.39	0.97
5%	117.12	0.29	0.96
10%	169.67	0.28	0.91
15%	219.56	0.19	0.98

Nugget moisture and fat content:

Batter formulation due to its level of FPC was significantly ($p<0.05$) influence on moisture loss in deep fat fried nugget. However, there have no significant ($p>0.05$) influence on air fried samples in case of moisture content. About deep fat fried samples, results showed that the addition of FPC up to the level of 10% leads to increase moisture, however the higher level (15%) decreased moisture content. It is worth to be noted that standard sample (with no FPC in batter) and nugget contain 5% FPC had the lowest and highest moisture content respectively in air fried samples (Fig 2).

Fat uptake was not significantly ($p>0.05$) influenced by FPC in the batter formulation in both deep fat and air frying. Analysis represented that the addition of FPC up to level of 10% in batter formulation causes a reduction in fat uptake. In fact, fat uptake had the opposite trend of moisture loss. Air fried samples contain 10% FPC also had significantly lower fat content than the others (Fig 3).

The higher moisture retention and consequently lower oil uptake may be related to the higher water holding capacity of FPC compared to the wheat flour and preventing water vaporization followed by lower porosity. Gamble et al. (1987); Krokida et al. (2000); Ufheil & Escher (1996); Ngadi et al. (2007) also reported the same results. Furthermore, they presented a negative linear relationship between moisture and oil content. Dogan et al. (2005) found that the soy flour in soy flour added batter can control water loss and oil uptake due to its high water binding capacity. Aminlari et al. (2005) used protein coating in order to reduce in water loss and oil absorption during frying.

Our finding about fat uptake reduction in protein based batter verified by He et al. (2015) using fish protein hydrolysates, Dehghan Nasiri et al. (2010) using soy flour and Dogan et al. (2004), using soy and rice flour in batter formulation. As Salvador et al. (2005) reported, greater fat absorption attributed to the lower moisture retention during frying. FPC in batter formulation caused crust to be able to retain a higher amount of moisture and absorbed relatively lower oil than the control in the frying process. This important quality factor attributed to the higher water holding capacity of FPC and higher viscosity of batter containing FPC. High viscosity batter considered as a factor to control of moisture releasing and oil absorption during frying.

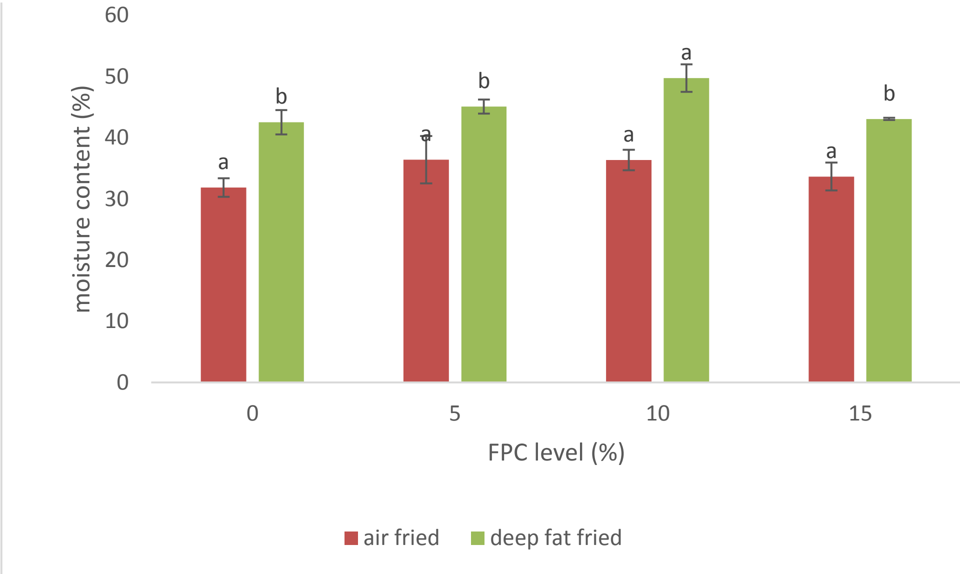

Fig. 2. Changes in moisture content by different level of FPC in batter formulation

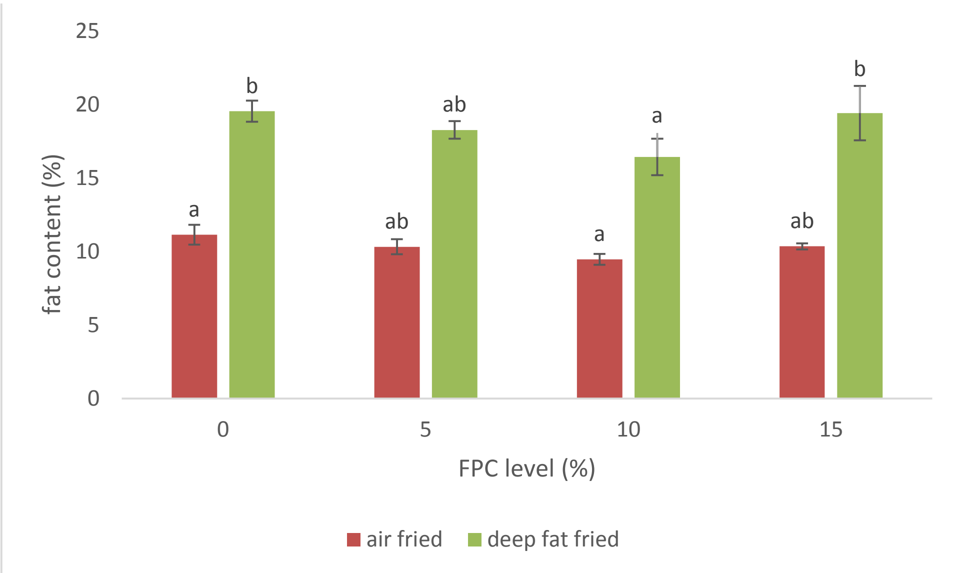

Fig. 3. Changes in fat content by different level of FPC in batter formulation

Crust thickness

Results of crust thickness analysis are presented in fig 4. The level of FPC significantly ($p<0.05$) affect the crust thickness in deep fat frying. Results showed that the thicker crust was obtained by the higher level of FPC in batter formulation and vice versa.

Air fat fried samples had the same trend of deep fat fried samples in terms of crust thickness however, the effect of FPC level on crust thickness was not significant ($p>0.05$).

Oil absorption and distribution depends on several factors, however; it mostly occurs in the crust region (Gamble *et al*., 1987; Keller *et al*., 1986; Pinthus *et al*., 1995). Therefore, crust considered as a critical factor of oil distribution in fried food (Varela, 1988). Mariscal and bouchon, (2008) stated that the formation of crust during the pre-drying step causes the vacuum fried apples loss lower amount of water. Pinthus et al. (1995) has studied thickness as one of crust physical properties and oil uptake. They stated that developing the crust as a mass transfer resistance factor causes the frying process a mass transfer limiting process. McHugh et al. (1993) reported that mass transfer resistance of edible films attributed to the increasing of film thickness. Thickness as an important crust property can affect the oil absorption of fried food during the process. In the research performed by Moriera. (2004), chips with a thicker crust had lower total oil saturation. The analysis in the current research has shown that the oil uptake was affected by crust thickness, as increasing the crust thickness under the influence of FPC in batter formulation resulted to a decrease in oil uptake of final fried food.

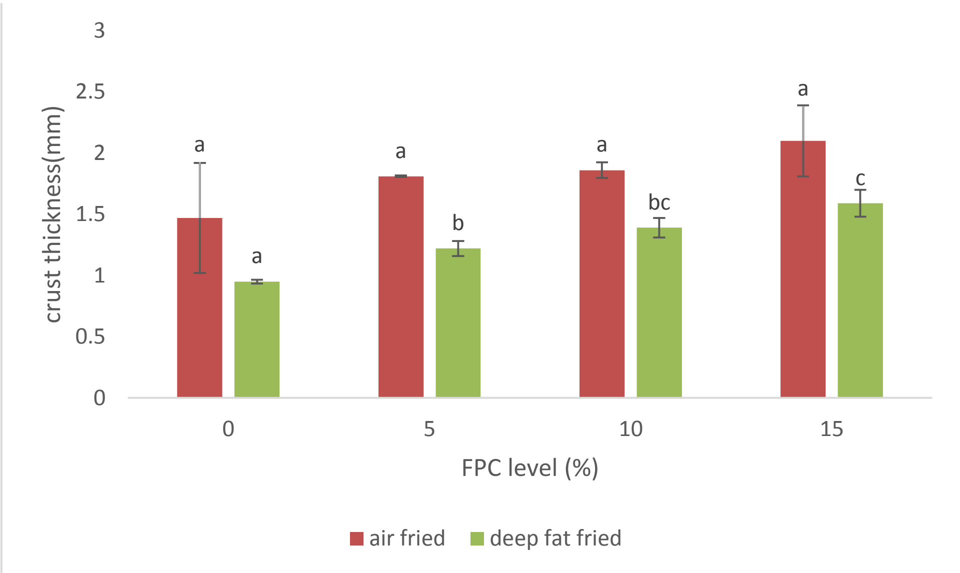

Fig. 4. Crust thickness influenced by different level of FPC in batter formulation

Sensory analysis

Texture was significantly ($p<0.05$) influenced by the level of FPC in batter formulation of air fried samples. However, the same factor was not significantly ($p>0.05$) influenced by the level of FPC in batter formulation of deep fat fried samples.

Addition of FPC in batter formulation had significant ($p<0.05$) influence on overall acceptability in both air and deep fat fried sample (Table 4).

Results of analysis showed that the addition of FPC up to level of 10% leads to higher score in texture evaluated by panelist and the sample contains of 15% had the least score among them.

Sample contains of 5% FPC in batter had the highest score in terms of overall acceptability in both types of frying.

Macaroni supplemented with 10% FPC was the most acceptable ones in terms of sensory properties (Costa *et al*., 1990). Shaviklo et al. (2010) noted that 7% fish protein powder fortification of corn snack was more acceptable than the other in terms of texture and overall acceptability. Moreover, Shaviklo et al. (2010) reported that the ice cream fortified with or without fish protein powder had similar sensory quality.

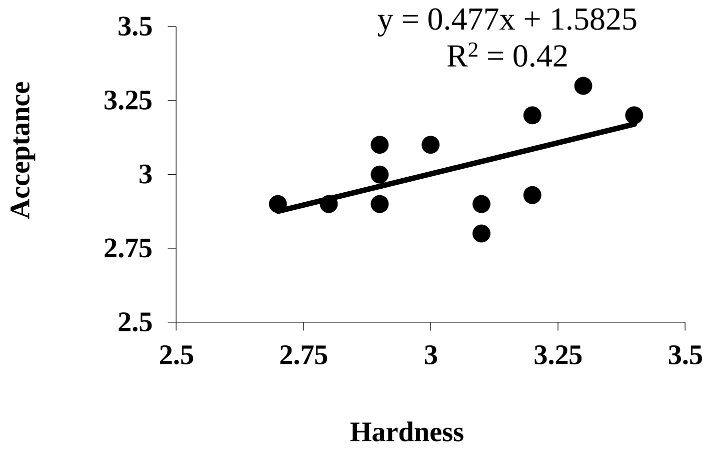

Fig. 5. Corelation between hardness and acceptance

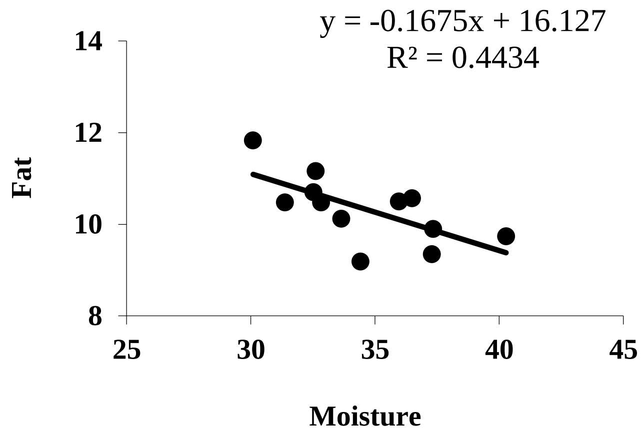

Fig. 6. Corelation between fat and moisture content

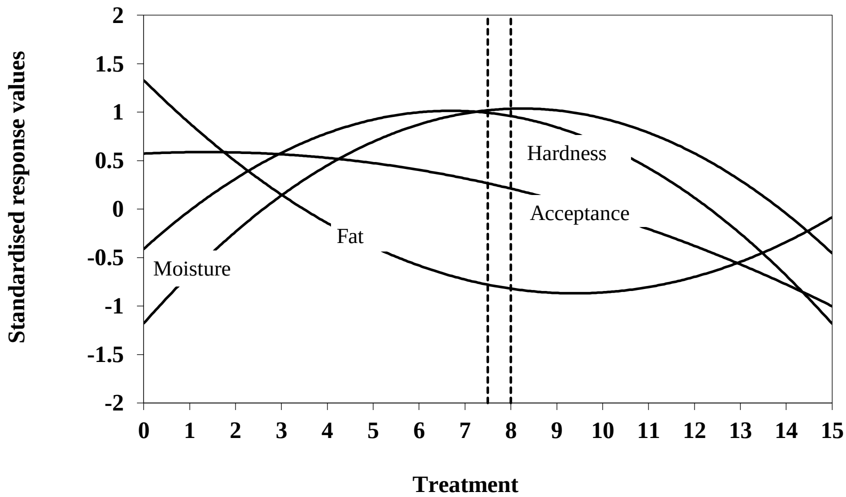

Fig. 7. Desirability diagram

Table 4- Effect of different level of FPC on texture and overall acceptability

Treatment (% FPC)	Texture (air fried)	Texture (deep fat fried)	Overall acceptability (air fried)	Overall acceptability (deep fat fried)
0	$2.93^a \pm 0.057$	$3^a \pm 0.1$	$3.06^b \pm 0.057$	$3.5^b \pm 0.0$
5	$3.3^c \pm 0.01$	$3.66^b \pm 0.3$	$3.23^c \pm 0.057$	$3.73^c \pm 0.057$
10	$3.13^b \pm 0.057$	$3.26^{ab} \pm 0.057$	$2.87^a \pm 0.068$	$3.4^b \pm 0.1$
15	$2.8^a \pm 0.1$	$3.03^a \pm 0.45$	$2.9^a \pm 0.0$	$3.1^a \pm 0.1$

Mean value in each column with different color differ significantly ($p<0.05$)

Maneerote et al. (2009) reported that the overall acceptability of cracker with 10 g/100 g of fish powder content was slightly higher than the crackers with 5g/100 g of fish powder content.

The aim of this research was to reach a product with low fat content along with an ideal range of moisture content, high score in terms of texture and overall acceptability. Desirability is the best way of description of the aim in the current research.

Based on desired factors and according to desirability approach optimization, the relationship between texture and overall acceptability, as well as moisture and fat was statistically significant. Results, illustrated in fig.5 indicated that 42% of changes in product acceptability are characterized by texture. Hence, texture considered a substantial component to assess overall acceptability. Based on the regression model, each unit score increase in texture, results in 0.48 increase of overall acceptability. Moreover, results illustrated in fig.6 are shown that 44% of changes in fat content are characterized by moisture content. Each unit change in moisture content, causes 0.17 unit change in fat content however in a reverse trend.

In order to display variables with no similar unit of measurement in the same figure, they should be standardized. Then the standard data is drawn in a figure based on the quadratic model. Suggested model shows that 7.5-8% of FPC can keep the response in an optimized level (Fig 7).

Conclusions

Based on our priorities, the experimental results showed that FPC is preferred to wheat flour however up to level of 7.5-8% in batter formulation. Hence, FPC can be an appropriate alternative of wheat flour in battered products as a functional ingredient. Results showed that low value fish can be value added by using in processed food products. Although, further research is needed to apply them in other products.

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استفاده از کنسانتره پروتئین ماهی در فرمولاسیون خمیرآبه جهت تهیه ناگت مرغ کم چرب

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چکیده

تاثیر سطوح مختلف (۵،۱۰ و ۱۵٪) پودر پروتئین ماهی در فرمولاسیون خمیرآبه مورد بررسی قرار گرفت. به‌منظور دستیابی به مقدار بهینه پودر پروتئین ماهی، خصوصیات فیزیکوشیمیایی ناگت مرغ ارزیابی شدند. رفتار جریان خمیرآبه نشان داد که نمونه خمیرآبه شاهد و نیز نمونه حاوی ۷/۵ درصد ویسکوزیته بالاتری نسبت به دیگر نمونه‌ها داشتند. در هر دو روش سرخ کردن (سرخ کردن عمیق و هوا سرخ‌کن) افت رطوبت و جذب روغن در نمونه شاهد بالاتر از نمونه‌های حاوی پودر پروتئین ماهی بوده است. پوسته ضخیم‌تر که نتیجه مقدار بیشتر پودر پروتئین ماهی در خمیرآبه می‌باشد سبب جذب روغن کمتر طی سرخ کردن شده است. به‌علاوه، نمونه‌های حاوی پودر پروتئین ماهی امتیاز بالاتری از نظر بافت و پذیرش کلی کسب کرده است. علی‌رغم اینکه ناگت‌های حاوی پودر پروتئین ماهی اولویت‌های این تحقیق را برآورده کرده‌اند اما مقادیر حدود ۱۵ درصد سبب ایجاد محدودیت‌هایی شدند و بر اساس بهینه‌یابی مطلوبیت مقادیر ۸- ۷/۵ درصد پودر پروتئین ماهی در فرمولاسیون خمیرآبه به‌عنوان بهترین مقادیر تعیین شدند.

واژه‌های کلیدی: ناگت مرغ، مطلوبیت، پودر پروتئین ماهی، سرخ کردن، کاهش جذب روغن

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