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Development of Low-Fat Functional Pork Nuggets with Incorporation of Whey Protein Concentrate

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ABSTRACT

Three different levels of whey protein concentrate viz. 3%, 5% and 7% were incorporated as fat replacers in pork nuggets after replacing the fat in the prestandardized formulation of pork nuggets and were compared with high fat control with 10% added fat. The control and treatment products were analysed for physicochemical parameters, proximate composition, instrumental colour profile, texture profile analysis and sensory evaluation. The pH of the treated pork nuggets incorporated with whey protein concentrate was significantly ($P<0.05$) lower than the control. Cooking yield, moisture, protein and ash followed an increasing trend on incorporation of whey protein concentrate. The fat content was significantly ($P<0.05$) reduced among all the treatment products. The values for the most of instrumental colour profile and texture profile were comparable among the control and treatment products. Sensory scores for all parameters were awarded significantly ($P<0.05$) higher for the pork nuggets incorporated with 5% whey protein concentrate in comparison to other treatment products.

Keywords: *Cooking yield, texture, low fat, instrumental colour profile*

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INTRODUCTION

Scientific evidences have confirmed the relationship between food and health and this has promoted the rapid development of a new concept of "Functional Foods". As per definition these are the products which in addition to acting as nutrients may positively affect specific biological functions, improve general state of health and/or reduce the risk of specific diseases (Diplock et al., 1999). Modern consumers are increasingly interested in their personal health, and expect the foods they eat to be – beyond tasty and attractive – also safe, healthy and cheaper. Modern consumers are no longer satisfied with the traditional meat products and often associate meat and meat products with negative health image due to its high levels of saturated fatty acids, cholesterol, sodium, absence of dietary fibre and high fat and calorie contents (Whitney and Rolfes, 2002) and their association with chronic diseases such as cardiovascular diseases, some types of cancer and obesity (Chan, 2004). Therefore, the demand of meat products with incorporated functional ingredients has sharp rise in recent years (Zhang et al., 2010).

Demand for nutritious and healthy food products, shifts the attention of processed meat producers toward processed meats that are lean, low fat and high in protein content. Health concerns about fat utilization and changes in consumer's preferences have led to comprehensive research on low-fat foods (Yang et al., 2007). Many non-meat protein rich ingredients have been utilized as fillers, binders and extenders in emulsion-based meat products to reduce the cooking losses and formulation cost besides improving product yield, nutritive value and functionality. Whey protein concentrate and milk co-precipitate are very good non-meat proteins with fat replacing and excellent binding properties. The gel obtained from the processed whey protein exhibits high water retention capacity and superior elasticity (Sato et al., 2002).

The development of meat products with low-fat content is usually accomplished by using raw material that have the property to bind water, thus being overtaken the high dry matter content, rubberiness and improves the juiciness (Tabarestani and Tehrani, 2014). The active approach is replacement of fat with fat substitutes or fat mimetics systems such as water (Ahmed et al., 1990; Kumar and Sharma 2003), proteins (wheat, maize, soy, milk, egg) (Ahmed et al., 1990), carbohydrates (starch, pectin, cellulose, gums, maltodextrins) (Ahmed et al., 1990) and fat-based fat substitutes (Akoh 1998; Keeton, 1994; Kumar and Sharma 2003). Protein based fat replacers were widely accepted as whey protein concentrates in sausages (Serdaroglu and Sapanci-Ozsumer 2003), milk powder and whey powder in turkey rolls (Serdaroglu and Deniz, 2003), milk proteins in chicken sausages (Rao et al., 1999), milk co-precipitates in the buffalo meat (Kumar et al. 2003) and others include reported the use of defatted melon kernel flour in beef sausages (Igyor et al., 2008), modified starches in meat batter (Aktas and Genccelep, 2006). In the light of above discussion, to develop low fat functional pork nuggets, the level of whey protein concentrate was standardized in the present study.

MATERIALS AND METHODS

Source of materials: For pork, female pig of large white Yorkshire breed was slaughtered in experimental slaughter house of Department of Livestock Products Technology, College of Veterinary Science, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India. Refined vegetable oil, refined wheat flour, condiments, table salt and spices were procured from local market of Ludhiana, Punjab, India. Tetra sodium polyphosphate (Hi media laboratories Pvt, Ltd., Mumbai, India) used in product preparation were procured from reputed firms.

Formulation of pork nuggets: Formulation and processing protocols of the pork nuggets was standardized on the basis of available literature and various preliminary trials conducted in laboratory. The standardized formulation is as follow: Pork

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(70 %), Ice/Chilled water (9%), Vegetable oil (10%), Condiments (3.80%), Salt (1.60%), Refined wheat flour (3.50%), Dry spices (1.50%), STPP (0.30%), Sugar (0.30), Nitrite (100 ppm).

Preparation of pork nuggets: Pork required for the experiment was partially thawed overnight, cut into small cubes and double minced through 4 mm plate in meat mincer (Mado Eskimo Mew-714, Mado, Germany). Meat emulsion was prepared in a bowl chopper (Seydelmann K20, Ras, Germany). Preweighed quantity of minced pork, salt, sodium tripolyphosphate and sodium nitrite was added and chopping was done for about 2-3 minutes. It was chopped again for 2 minutes after the addition of ice flakes. Refined vegetable oil was slowly incorporated while chopping till it was completely dispersed in the batter. Condiment paste, dry spice mix, refined wheat flour and other ingredients were added. Chopping was continued till uniform dispersion of all the ingredients and desired consistency of the emulsion was achieved. Meat emulsion of about 500 gm was filled in stainless steel moulds. These were kept for steam cooking at 121°C for 30 min. Uniform cutting of meat blocks was done with the help of sharp knife to prepare the pork nuggets. These were packaged and stored under refrigeration.

Preparation of low-fat functional pork nuggets: Low-fat functional pork nuggets were prepared with the incorporation of different levels of whey protein concentrate as: T1- pork nuggets with 3% WPC, T2- pork nuggets with 5% WPC and T3- pork nuggets with 7% WPC after replacing the fat in standardized formulation of pork nuggets. The formulation of control and treatment products (T1, T2 and T3) is given in Table 1.

Table 1: Formulation of the pork nuggets

S. No.	Ingredients	Percentage (w/w)			
		Control	**T1**	**T2**	**T3**
1	Pork	70.00	70.00	70.00	70.00
	Ice/Chilled water	9	9	9	9
	Vegetable oil	10	7	5	3
	Condiments	3.80	3.80	3.80	3.80
	Salt	1.60	1.60	1.60	1.60
	Refined wheat flour	3.50	3.50	3.50	3.50
	Dry spices	1.50	1.50	1.50	1.50
	STPP	0.30	0.30	0.30	0.30
	Sugar	0.30	0.30	0.30	0.30
10	Nitrite	100 ppm	100 ppm	100 ppm	100 ppm
11	Whey Protein Concentrate	Nil	3	5	7

Analytical procedures

pH: The pH of emulsion and pork nuggets was determined as per the method described by Trout et al. (1992) with digital pH meter (FE-20-1-KIT, Mettler-Toledo India Pvt. Ltd., Mumbai) equipped with a combined glass electrode. 10 gram of sample was homogenized with 50 ml of distilled water for 1 min. using pestle and mortar. The electrode was dipped into the suspension and the pH value of the sample was recorded.

***Water activity (a_w)*:** Water activity of emulsion as well as product was determined by using hand held portable digital water activity meter (Rotronic Hygro Palm AW1 Set/40 USA). Meat (emulsion or finely ground pork nuggets) was filled up (≈80%) in moisture free sample cup and water activity was recorded as per specifications. Duplicate readings were recorded for each sample.

Cooking yield: The weight of each product was recorded before and after cooking. The cooking yield was calculated and expressed as percentage by a formula:

$$\text{Cooking yield (\%)} = \frac{\text{Weight of cooked product}}{\text{Weight of raw pork emulsion}} \times 100$$

***Proximate composition*:** The moisture, protein, fat, and ash content of the product was estimated using automatic moisture analyzer, Kel plus (Pellican Equipments), Socs Plus (Pellican Equipments) and Muffle furnace (Macro Scientific Works.), respectively following the method of AOAC (1995).

***Texture profile analysis (TPA)*:** Texture profile analysis (TPA) was conducted using Texture Analyzer (TMSPRO, Food Technology Corporation, USA). Sample size of 1cm ×1cm ×1cm was sub-

jected to pretest speed (30mm/sec), posttest speed (100mm/sec) and test speed (100mm/sec) to a double compression cycle with a load cell of 2500 N. A compression platform of 25 mm was used as a probe. TPA was performed as per the procedure outlined by Bourne (1978). Parameters like hardness, springiness, stringiness, cohesiveness, chewiness, gumminess and resilience were calculated automatically by the preloaded Texture Pro software in the equipment from the force time plot. Six reading were recorded for each sample.

***Hardness*:** It is the height of the force peak (F2) on the first compression cycle (first bite is defined as hardness). It is expressed in N (force). It is defined as maximum force to compare the sample.

***Springiness*:** It is the distance, which the food recovered its height during the time that elapsed between the end of the first bite and start of the second bite. Originally this is known as elasticity. It is calculated from the ratio of time-diff: 4:5 (T-2) and time-diff: 1:2 (T-1) i.e. T-2/T-1. It is defined as ability of sample to recover its original shape after the deforming force. It is expressed in mm.

***Cohesiveness*:** It is defined as ratio of Area-FT 4:6 (A2) and Area –FT 1:3 (A1) and expressed in N.

***Gumminess*:** It is defined as the product of hardness and cohesiveness i.e. F2 × (A2/A1) and expressed in N.

***Resilience*:** It is defined as area during the withdrawal of the first compression divided by the area of the first compression (Area 5/ Area 4) on the graph.

Colour profile analysis: Colour profile was measured using CR-400 Konica Chroma meter (Konica Minolta, Japan) set at 2° of cool white light (d65) and known as "L", a and b values. "L" value denotes (brightness 100) or lightness (0), a (+ redness/- greenness), b (+ yellowness/-blueness) values were recorded on hundreds of pork nuggets kept in a plate. The instrument was calibrated using light trap (black hole) and white tile provided with the instrument. Then the above colour parameters were selected. The instrument was directly put on the surface of pork nuggets at three different points. Mean and standard error for each parameter were calculated. Delta e (total colour difference) can be calculated by using following formula

$$\Delta E = \sqrt{(l^*_2 - l^*_1)^2 + (a^*_2 - a^*_1)^2 + (b^*_2 - b^*_1)^2}$$

Statistical analysis: Data was analyzed statistically on "SPSS-16.0" (SPSS Inc., Chicago, II USA) software package as per standard methods (Snedecor and Cochran 1994). Duplicate samples were drawn for each parameter and the whole set of experiment was repeated three times to have total number of observations. Sensory evaluation was performed by a panel of seven member judges, Total observations of all parameters were six (n=6) except sensory parameters where n=21. The average values were reported along with standard error. The statistical significance was estimated at 5% level (P<0.05) and evaluated with Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Three different levels of whey protein concentrate viz. 3%, 5% and 7% were incorporated as fat replacers in pork nuggets after replacing the fat in the pre-standardized formulation of pork nuggets and were compared with high fat control with 10% added fat. The control and treatment products were analysed for physico-chemical parameters, proximate composition, instrumental colour profile, texture profile analysis and sensory evaluation.

Physico-chemical parameters and proximate composition of pork nuggets incorporated with whey protein concentrate: The values for physico-chemical parameters (pH, cooking yield and water activity) and proximate composition (moisture, protein, fat, ash and moisture protein ratio) of pork nuggets incorporated with three different levels of whey protein concentrate are presented in Table 2.

Table 2: Effect of incorporation of different levels of whey protein concentrate on physico-chemical properties and proximate composition of pork nuggets (Mean±S.E.)*

Parameters	Physico-chemical properties			
	Control	T_1 (3% WPC)	T_2 (5% WPC)	T_3 (7% WPC)
pH	5.43±0.01[a]	5.22±0.004[b]	5.19±0.004[c]	5.19±0.007[c]
Water activity (a_w)	0.97±0.002	0.97±0.002	0.97±0.002	0.97±0.003
Cooking Yield (%)	92.79±0.04[d]	93.72±0.11[c]	94.76±0.15[b]	95.70±0.06[a]
	Proximate composition			
Moisture (%)	66.15±0.01[d]	68.44±0.18[c]	70.14±0.16[b]	72.12±0.44[a]
Fat (%)	12.39±0.18[a]	8.19±0.13[b]	5.59±0.18[c]	4.11±0.12[d]
Protein (%)	17.27±0.09[d]	19.59±0.10[c]	20.69±0.08[b]	21.28±0.11[a]
Ash (%)	2.22±0.004[b]	2.24±0.012[b]	2.29±0.027[b]	2.31±0.003[a]
Moisture:Protein	3.83±0.02[a]	3.49±0.01[b]	3.39±0.01[c]	3.38±0.01[c]

N=6; C= Control (10% fat); T-1= 3% whey protein concentrate; T-2= 5% whey protein concentrate; T-3= 7 % whey protein concentrate.
Mean±S.E. with different superscripts differ significantly (P<0.05).

The pH of the treated pork nuggets incorporated with WPC was significantly (P<0.05) lower than the control. The pH of the pork nuggets ranged from 5.43 to 5.19. The lowest pH values (5.19) were of T-2 and T-3 indicating that the pH of the pork nuggets decreased with the increase in the level of WPC in the formulation, and this might be due to lower pH (5.12) of whey protein concentrate. There was no significant (P>0.05) difference in the water activity (aw) among the control and the treated products.

Cooking yield followed an increasing trend and there was significant (P<0.05) increase in the yield of the treatment product i.e from 92.79 to 95.70%. It might be attributed to improve emulsion stability due to appropriate protein:fat ratio which forms a compact structure to resist the fat and moisture losses during heating/cooking of the products. The results obtained in the present study were well in accordance with Rao et al. (1999) in smoked chicken sausages and Kesava et al. (1998) in low-fat mutton balls.

The moisture content of the product increased significantly (P<0.05) with increasing WPC in the formulation. The control had lowest moisture content (66.15%) whereas T-3 with 7% WPC had the highest moisture content (72.12%). It could be due to the more water binding property of WPC. The thermal treatment of WPC forms gel like structure which holds water and consequently higher moisture content in the product.

The fat content was significantly (P<0.05) reduced among all the treatment products due to deliberate reduction of fat content in the pork nuggets with the incorporation of WPC as fat replacer. The fat content ranges between 12.39% in control (highest) and 4.11% in T-3 (lowest). The reduction in fat content with incorporation of fat replacers was also reported by Berry (1994) in pork nuggets (gums and modified starches) and Zanardi et al. (2006) in salame milano (skimmed milk and dextrins).

Protein values were found significantly (P<0.05) higher in treated products than control due to addition of protein based fat replacers with high protein content (72%). The protein content in treated products was directly proportional to the added WPC content in the formulation. Ash content was recorded significantly (P<0.05) higher in T-3 than control values. Moisture-protein ratios were significantly (P<0.05) lower in treated products in comparison to control and decreased gradually with increase in WPC content in pork nuggets and recorded as per the calculations based on the respective moisture and protein values of the pork nuggets.

Instrumental colour profile of pork nuggets incorporated with whey protein concentrate: Lightness (L*), yellowness (a*) and redness (b*) values of pork nuggets incorporated with different levels of whey protein concentrate (3%, 5% and 7%) are presented in Table 3. The first stimulus for the consumer acceptability of meat and meat products is colour. L*, a* and b* values presented in table 2 differed significantly (P<0.05) due to incorporation of different levels of WPC. Lightness values of pork nuggets increased significantly (P<0.05) with increase in level of WPC. Lowest (lightness) values were observed in control (59.17) while highest values for T-3 (64.28) which shows that incorporation of WPC resulted in lighter coloured meat products. Redness (a*) values were decreased significantly (P<0.05) with the addition of WPC, higher the level of WPC lower the redness. Yellowness (b*) increased significantly (P<0.05) from 51.64 to 55.85 with the increase in incorporation level of WPC.

Table 3: Effect of incorporation of different levels of whey protein concentrate on instrumental colour profile of pork nuggets (Mean±S.E.)*

Parameters	Instrumental color			
	Control	T1 (3% WPC)	T2 (5% WPC)	T3 (7% WPC)
Lightness (L* value)	59.17±0.29^{d}	61.87±0.16^{c}	62.70±0.15^{b}	64.28±0.13^{a}
Redness (a* value)	14.15±0.14^{a}	13.84±0.11^{b}	12.94±0.08^{c}	11.94±0.09^{d}
Yellowness (b* value)	51.64±0.01^{d}	52.47±0.05^{c}	52.71±0.08^{b}	55.85±0.03^{a}

N=6; C= Control (10% fat); T-1= 3% whey protein concentrate; T-2= 5% whey protein concentrate; T-3= 7 % whey protein concentrate. *Mean±S.E. with different superscripts differ significantly (P<0.05)*.

Texture profile analysis of pork nuggets incorporated with whey protein concentrate: Three different levels of whey protein concentrate i.e. 3%, 5% and 7% were incorporated as a replacement of added fat in the prestandardized formulation of pork nuggets. The values for instrumental textural profile of pork nuggets are presented in the Table 4. A significant (P<0.05) decrease in the hardness and chewiness was observed in the treatments on incorporation of WPC. These were significantly (P<0.05) higher in control than all the treated products. It could be correlated with high moisture and low fat content in treatments than control. Stringiness and springiness were found to be significantly (P<0.05) higher in treated products than control. It was recorded highest (22.74 and

13.77) in control and lowest (19.38 and 11.51) in T3, respectively. It might be due to better emulsion formulation and gel like structure formed by WPC which attributed to improve elasticity and consequently stringiness of the product.

Gumminess decreased significantly (P<0.05) in the treated products than control this could be related with changes in the fat contents and other prominent variables in the developed product. Chewiness values were recorded significantly (P<0.05) lower in the treatment products than control. Resilience was also recorded significantly (P<0.05) higher in treated products than control.

Sensory evaluation of pork nuggets incorporated with whey protein concentrate: The scores of the sensory parameters (appearance, flavour, juiciness, texture and overall acceptability) for pork nuggets incorporated with three different levels of whey protein concentrate i.e. 3%, 5% and 7% are presented in Table 5.

Sensory scores for all the sensory attributes of pork nuggets varied significantly (P<0.05) with the addition of different levels of whey protein concentrate. Marketing of meat products at consumer level depends upon sensory quality of product. Appearance scores decreased with increase in whey protein concentrate levels but T2 stands highest amongst all. These results are in conformity with the observations recorded by chromo color meter. The diminution of meat flavour was noticed by the sensory panelists with the incorporation of higher amount of WPC on replacing lean meat whereas juiciness scores were correlated with the increase in moisture content in the developed products. However, textural scores were being awarded significantly (P<0.05) higher to T-2 than all the treatment products by the sensory panelist. These results can be correlated with the results of instrumental textural parameters. Low fat chicken patties (50% fat reduction) were also prepared by Chappalwar et al. (2020) with incorporating 1% lemon albedo with comparable sensory quality to the control product.

Table 4: Effect of incorporation of different levels of whey protein concentrate on texture profile analysis of pork nuggets (Mean±S.E.)*

Parameters	Texture Profile Analysis			
	Control	T1 (3% WPC)	T2 (5% WPC)	T3 (7% WPC)
Hardness (N/cm^2)	13.50±0.06^a	13.30±0.11^b	12.49±0.06^c	11.43±0.05^d
Stringiness (mm)	19.38±0.11^d	19.83±0.05^c	20.61±0.04^b	22.74±0.17^a
Springiness (cm/mm)	11.51±0.07^b	11.85±0.02^b	12.30±0.05^a	13.71±0.03^a
Gumminess (N/cm^2)	6.49±0.08^a	6.39±0.01^b	6.27±0.02^c	6.06±0.01^d
Chewiness (N/cm)	80.49±0.02^a	80.43±0.19^b	80.14±0.01^c	79.59±0.11^d
Resilience	0.60±0.06^c	0.63±0.03^c	0.65±0.06^b	0.69±0.01^a

N=6; C= Control (10% fat); T-1= 3% whey protein concentrate; T-2= 5% whey protein concentrate; T-3= 7 % whey protein concentrate. *Mean±S.E. with different superscripts differ significantly (P<0.05)*.

Table 5: Effect of incorporation of different levels of whey protein concentrate on sensory evaluation of pork nuggets (Mean±S.E.)*

Parameters	Sensory scores			
	Control	T1 (3% WPC)	T2 (5% WPC)	T3 (7% WPC)
Appearance	7.23±0.10^a	6.71±0.13^c	7.35±0.09^a	6.64±0.50^c
Flavour	7.38±0.08^a	6.80±0.18^b	7.33±0.07^a	6.45±0.16^c
Juiciness	7.28±0.05^a	6.95±0.14^b	7.28±0.05	6.73±0.18^b
Texture	7.28±0.07^a	6.69±0.13^b	7.40±0.08^a	6.71±0.28^b
Overall Acceptability	7.30±0.07^a	6.96±0.26^b	7.45±0.07^a	6.73±0.18^{ab}

n=21; C= Control (10% fat); T-1= 3% whey protein concentrate; T-2= 5% whey protein concentrate; T-3= 7 % whey protein concentrate. *Mean±S.E. with different superscripts differ significantly (P<0.05)*.

CONCLUSION

The low-fat functional pork nuggets can be developed by incorporating the whey protein concentrate at 5% level. The developed product had better physico-chemical, proximate composition, instrumental colour profile, texture attributes and sensory quality.

COMPETING INTERESTS: The authors have no known competing interests either financial or personal between themselves and others that might bias the work.

ETHICS STATEMENT: Not applicable.

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