DEVELOPMENT AND CHARACTERIZATION OF DUCK NUGGETS

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DEVELOPMENT AND CHARACTERIZATION OF DUCK NUGGETS

by

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LIST OF ABBREVIATIONS / SYMBOLS

Abbreviations / Symbols	Caption
AA	Arachidonic Acid
AAS	Atomic Absorption Spectroscopy
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
Ca	Calcium
CF	Corn Flour
CIE	Commission Internationale de I'Eclairage
CN	Chicken Nuggets
Cu	Copper
DHA	Docosa Hexaenoic Acid
DP	Degree Polymerization
DVS	Department of Veterinary Services
EPA	Eicosa Pentaenoic Acid
FA	Fatty Acids
FAMA	Federal Agriculture Marketing Authority
FAME	Fatty Acid Methyl Esters

FAS	Foreign Agricultural Service
Fe	Iron
FFA	Free Fatty Acids
g	Gram
GC	Gas Chromatograph
H_2O_2	Hydrogen peroxide
HCl	Hydro chloride
HDM	Hand Deboned Meat
HNO_3	Nitric Acid
ISP	Isolate Soy Protein
K	Potassium
KFC	Kentucky Fried Chicken
KH_2PO_4	Potassium dihydrogen phosphate
La_2O_3	Lanthanum oxide
LEAR	Low Erucic Acid Rapeseed
MARDI	Malaysian Agricultural Research and Development Institute
MDDM	Mechanically Deboned Duck Meat
MDM	Mechanically Deboned Meat

MDPM	Mechanically Deboned Poultry Meat
Mg	Magnesium
mg	Milligram
MSG	Monosodium glutamate
MT	Million Tones
MUFA	Mono Unsaturated Fatty Acids
Na	Natrium
NaCl	Natrium chloride
NaOH	Natrium hydroxide
P	Phosphorus
PER	Protein Efficiency Ratio
PF	Potato Flour
ppm	Part per million
PUFA	Poly Unsaturated Fatty Acids
R&D	Research and Development
RF	Rice Flour
SEAFDC	Southeast Asian Fisheries Development Centre
SEM	Scanning Electron Microscopy

SF	Sago Flour
SFA	Saturated Fatty Acids
SPSS	Statistical Package for Social Science
TEG	Terminal Extent of Gelatinization
TF	Tapioca Flour
UEA	United Arab Emirates
UK	United Kingdom
US	United States
USDA	United States Department of Agriculture
UV	Ultra violet
WB	Wet basis
WF	Wheat Flour
WHC	Water Holding Capacity
Zn	Zinc

PEMBANGUNAN DAN PENCIRIAN NUGET ITIK

ABSTRAK

Penghasilan piawai untuk pemprosesan nugget itik dengan kandungan proksimat dan sifat fisikokimia berasaskan nuget ayam telah dikaji. Julat kandungan lembapan, protein, lemak, abu dan karbohidrat untuk produk nugget ayam komersil dalam julat 34.71-56.51%, 12.52-16.62%, 18.14-25.00%, 1.20-1.58% dan 7.52-26.49%. Nilai L^*, a^* dan b^* nugget ayam komersil berjulat dari 64.38-68.41, 0.51-3.51 dan 16.46-19.35. Nilai kekunyahan nuget ayam komersil adalah sebanyak 12.66-18.55 N dan kebolehan mengikat air adalah antara 34.54-51.57%. Peratus kehilangan memasak pula dalam julat 3.37-3.05%. Julat kekerasan, kekohesifan, springiness, kekenyalan dan kelikatan masing-masing 33.36-77.45N, 0.61-0.80Ns, 1.00-1.23mm, 21.26-61.66N/mm^2 dan 23.02-66.13N/mm. Faktor pemprosesan ke atas perkembangan nuget daging itik yang telah dikaji ialah penggunan tepung, pemformulasian, minyak goreng dan pembasuhan daging. Sifat fisikokimia, struktur mikro dan penilaian deria nuget itik juga dinilai. Hasil penelitian menunjukkan bahawa kandungan air, lemak, protein dan kandungan karbohidrat berbeza secara signifikan (P<0,05) dengan penggunaan tepung gandum yang pelbagai dalam formulasi. Nilai L^*, a^* dan b^* nuget itik berjulat antara 56.97-60.33, 4.19-4.66 dan 19.19-19.98. Nuget itik yang dibuat daripada tepung gandum menunjukkan kadar kehilangan memasak yang lebih rendah manakala kekunyahan dan kebolehan mengikat air yang lebih tinggi. Nuget yang mengandung tepung gandum menunjukkan penerimaan keseluruhan yang lebih tinggi apabila dibandingkan dengan sampel yang lain. Pemformulasian nuget itik dengan nisbah 30% tepung dan 70% daging itik adalah optimal dari segi komposisi kimia, warna, tekstur dan penilaian deria yang bersesuaian dengan nuget komersil.

Kehilangan memasak nuget itik dengan menggunakan minyak goreng canola menunjukkan nilai yang lebih rendah dan tidak berbeza secara signifikan (*P*>0,05) berbanding dengan minyak goreng lain. Faktor pembasuhan dilakukan untuk meningkatkan penerimaan dan menunjukkan perbezaan secara signifikan (*P*<0,05) keatas nilai kecerahan (*L**) dan kekuningan (*b**) nuget daging itik. Perlakuan pembasuhan nyata berkesan keatas tekstur nuget daging itik, perbezaan yang signifikan (*P*<0.05) keatas pH, kekunyahan, kehilangan memasak dan kebolehan mengikat air daripada dua dan tiga kali pembasuhan. Nuget daging itik daripada perlakuan pembasuhan menunjukkan warna, aroma, rasa, kekenyalan, kekerasan, kejusian dan penerimaan keseluruhan adalah berbeza secara signifikan (*P*<0,05). Nuget daging itik yang diperbuat daripada pembasuhan daging itik nyah tulang mekanikal dengan dua kali pembasuhan lebih stabil, sekata dan diterima dari segi faktor kualiti.

DEVELOPMENT AND CHARACTERIZATION OF DUCK NUGGETS

ABSTRACT

Establishment of standards for duck nugget processing with data proximate and physicochemical characteristics based on chicken meat has been studied. The percentage range of moisture, protein, fat, ash and carbohydrate contents of commercial chicken nuggets ranged was between 34.71-56.51%, 12.52-16.62%, 18.14-25.00%, 1.20-1.58% and 7.52-26.49%, respectively. The *L**, *a** and *b** values of commercial chicken nuggets ranged between 64.38-68.41, 0.51-3.51 and 16.46-19.35, respectively. The toughness of commercial chicken nuggets was ranged between 12.66-18.00 and water holding capacity was ranged between 34.54-51.57%. Cooking loss value was ranged between 3.37-13.05%. Texture profile analysis showed the hardness, cohesiveness, springiness, gumminess and chewiness was ranged between 33.36-77.45N, 0.61-0.80Ns, 1.00-1.23mm, 21.26-61.66N/mm^2 and 23.02-66.13N/mm, respectively. The processing factors studied in the development of duck nugget including the types of flours, ratios of wheat flour used in the formulations, frying oils and washing treatments. Sensory properties of duck nugget were evaluated. The results showed that moisture, fat, protein and carbohydrate contents were significantly different ($P<0.05$) with the variation of wheat flour used in the formulations. The *L**, *a** and *b** values of cooked duck nuggets was ranged between 56.97-60.33, 4.19-4.66 and 19.19-19.98, respectively. Duck nugget made with wheat flour showed lower cooking loss, higher toughness and water holding capacity similarly it showed highest overall acceptability compared to other samples. The formulation of duck nugget with the ratio of 30% wheat flour and 70% duck meat was similar in chemical composition, colour, textural properties and sensory evaluation of commercial chicken nugget. Cooking loss of duck nugget fried with canola oil showed lower value although there was no significant difference (P>0.05) compared to other frying oils. In general, washing treatment enhanced acceptability of duck nugget. Significant differences (P<0.05) were found in lightness (L*) and yellowness (b*) value. Washing treatment was found to affect textural properties of duck nugget, however there was no significant difference (P<0.05) in pH, toughness, cooking loss and water holding capacity of duck nuggets prepared from the meat washed with only two or three washing cycle. Duck meat nuggets from washing cycles showed colour, odour, taste, gumminess, hardness, juiciness and overall acceptability that were significantly different (P<0.05). The duck nuggets made from mechanically debone duck meat that had been through a two washing cycles were found to be more stable, uniform, and showing high acceptability in terms of quality.

CHAPTER 1

INTRODUCTION

1.1 Background

In recent years, several studies have been conducted in many countries in the world on how to increase the per capita consumption of poultry meat. USDA (2007) reported the poultry meat per capita consumption was dominated by three biggest countries, namely United Arab Emirates (54.9/kg/person), Kuwait (50.7/kg/person) and United States (45.1/kg/person). Meanwhile, total per capita consumption of poultry meat in Malaysia in 2007 was 38.9/kg/person and placed in the fourth among 28 countries recorded by USDA. The production of poultry meat showed an increasing trend since 2003-2007, with 59.888.000 MT, 61.313.000 MT, 64.583.000 MT, 65.499.000 MT and 67.992.000 MT, respectively. Meanwhile the consumption of duck meat also showed the similar trend with production of 58.329.000 MT, 59.435.000 MT, 62.674.000 MT, 64.165.000 MT and 66.082.000 MT. The Department of Veterinary Services Malaysia (2007) had reported the consumption of poultry meat increase significantly since 2002 until 2006, there are 781.970 MT, 797.850 MT, 860.390 MT, 785.660 MT and 828.730 MT, respectively.

Poultry is among the most popular food products world-wide and consumer demand is at least partly due to the desirable flavour of poultry products (Barker and Bruce, 1995). Consumption of poultry meat and poultry meat products is currently growing and the increased production of cut-up and processed meat has provided considerable quantities of parts suitable for mechanical deboning. With the growing demand for poultry meat, the duck industry has commenced to follow the same pattern of the broiler industry. This could be seen in the establishment of more specialized business venture with modern poultry slaughterhouse, processing for better packaging and presentation to consumers. The total population of duck in Malaysia in 2006 is 8.138.777 and for the duck broiler is 6.710.493 (Department of Veterinary Services, 2007).

There are various types of ducks found in Malaysia, such as Muscovy duck, Local Java duck, Peking duck and mixed duck of male Muscovy with female Peking, which is called the Mule duck (Yeong *et al*., 1993). Duck meat normally obtained from the parts of chest and thigh. The meat from thigh usually is darker in colour and more fat content compared to chest meat. The colour of duck meat is darker as compared to chicken and turkey meat. Duck has one layer of fat under the skin between skin and flesh (Anon, 2007).

Fast food can be defined as food that is fully and rapidly prepared by seller in short time. It can be consumed directly without any further process at seller's premise and can be packed to be taken away to home. In this country fast food is always associated with fast food restaurant such as Kentucky Fried Chicken (KFC), A&W and McDonald.

Fast food industry caused the increase in meat based value added product especially derived from farmyard birds. Production of value added product could increase in a variety of output production and optimize in the usage of by-product for the industrial process of farmyard birds. One of the bird based value added product was nugget.

The nugget was one of the quite new products in Malaysia. Most of the nugget in the market was made of chicken. Meanwhile, production of nugget from other birds such as duck should be emphasized. However, there are limited publications available on the production of nugget from duck meat, unlike other products such as burger, sausage and frankfurter where more references are available.

The effort in breeding duck was a small part of bird poultry industry. This was caused by the increase in number of population and buying power among local people (Yeong *et al.*, 1993).

Hence, various Malaysian government agencies such as Malaysian Agricultural Research and Development Institute (MARDI), Department of Veterinary Services Malaysia (DVS), Federal Agriculture Marketing Authority (FAMA) and others had taken some steps to increase the production of duck meat in the local and overseas market. Besides, government had launched many campaigns to encourage consumption of duck meat in daily menu because duck meat was believed in nutrition as source of protein, minerals and vitamins.

The development of value added product, such as nuggets has been identified as the best way to increase duck consumption. Nuggets are restructured meat product with batter and coating to improve the quality. The main component of a nugget is meat, usually from chicken, fish or combination with vegetable protein and gum. The composition of the batter is flour. In Malaysia chicken nuggets is commonly served at almost all fast food restaurant chains. Proximate composition and physicochemical characteristics of chicken nuggets are the most significant factors for consumer acceptability.

According to the Malaysian Food Regulation (1985) restructured meat products must contain not less than 65% meat in a formulation. USDA (1991) suggested the coating of a nugget should be less than the weight of the meat. The quality of a nugget can significantly be affected by processing, raw materials, and ingredient factors, either from nutritional value or overall acceptability of consumers. Only those nuggets with high nutritional value, low cholesterol, good textural properties, nice flavour and taste profile will become the favourite choice of consumers.

Flours are derived from wheat, barley, corn, rice, millet and oat. Flour is the main ingredient in coating for fritters (Olewnik and Kulp, 1993). The quality factor of flours depending on its type (hard or soft), protein level, starch damage, flour added with amylolitic enzymes (from cereal or fungi), proteolytic enzymes and addition of oxidants such as potassium bromate and potassium iodate.

Wheat flour is the major ingredient, and is used in coating at 30%-50% of the fried product (Loewe, 1990). In Asian market wheat flour is quite expensive as compared to other flours. Flours often used as alternative to wheat flour including rice, tapioca, sago, potato and corn flours. Flour, with starch being the main component, belongs to the polysaccharide group. In coating, polysaccharide could interact with protein to provide stability for wrapping or breads and interacts with lipid to contribute to emulsion effect or viscosity.

Flours in the market have various features and physicochemical characteristics. In the bakery industry, selection of suitable flour is very important to produce products with good quality (Olewnik and Kulp, 1993). For frying the selection of suitable flours is essential as it affects flavour, colour, texture and crispness of the products.

Deep-fat fried foods have unique characteristics such as smooth mouth feel, distinctive flavour, colour and palatability. Some fried products may contain high amount of fat due to the normal fat absorption during deep-fat frying (Mackinson *et al.*, 1987). Consumer awareness of the health implications of consuming foods high in fat is increasing (Ngadi *et al.*, 2007; Krokida *et al.*, 2001). Therefore, there is much interest in reducing fat uptake during deep-fat frying. Although there have been studies on fat absorption during frying, the mechanism of oil uptake is still not well understood. Fried food quality depends on the kind of fuel used and types of food deep fried. Oil temperature during frying and kind of equipment or fryer could also exert influence on food quality.

Mechanically deboned meat (MDM) has significantly higher quantities of sarcoplasmic and non-protein nitrogen than hand deboned meat (HDM), while no significant difference was found between the levels of myofibrillar protein for the two treatments (Webb *et al*., 1976). Ang and Hamm (1982) found that HDM and MDM have similar protein contents while Satterlee *et al*. (1971) reported that as skin content increased, protein content decreased.

Yield of mechanically deboned poultry meat (MDPM) ranges from 55% to 80%, depending on the part deboned and deboned settings (Mielnik *et al.*, 2001). The darker colour from the higher heme content of MDPM is undesirable in poultry meat products directed towards the white meat market.

Washing techniques for mechanically deboned poultry meat have been investigated because of the advantages of removing fat, heme pigments and other water soluble compounds (Dawson *et al.*, 1988; Dawson *et al*., 1989; Yang and Froning, 1992). In the washing process, poultry meat heme removing is important because white meat is more valuable than dark meat (Yang and Froning, 1994).

Thus, we conducted the development of restructured products made from a poultry meat for improvement of unpopular meat.

Several studies on the process and characteristics of washed mechanically deboned chicken meat have been reported. However, there has been no report on the process and characteristics of washed mechanically deboned duck meat (MDDM) in nuggets formulation to improve quality and acceptability of nuggets from duck meat.

1.2 Objectives of study

The objectives of this study were:

1. To establish of standards for duck nugget processing with data proximate and physicochemical characteristics of chicken meat based nuggets.

2. To elucidate the effects of processing factors on the development of duck meat nugget:

    a. Effect of different flour on the quality and sensory of duck meat nugget.

    b. Effect of wheat flour and meat ratio on the quality and sensory of duck meat nugget.

    c. Effect of different types of frying oil on the quality and sensory of duck meat nugget.

    d. Effect of washing of the mechanically deboned duck meat on the quality and sensory of duck meat nugget.

CHAPTER 2

LITERATURE REVIEW

2.1 Consumption of livestock poultry in the World and Malaysia

In the year of 2005, breeding industry directly enforced to achieve trade balance reducing in breeding subsector. Efforts had been made to focus on activities of local breeding industry with control program to eliminate poultry diseases. Furthermore, production of product from breeding industry was strengthened from quality to '*halal*' status in order to export the products to overseas especially Islamic countries. This industry was estimated to expand to fulfill the food demands in our country and the raw material demands for food processing industry in producing poultry based products in the local and overseas market (Anon, 2007).

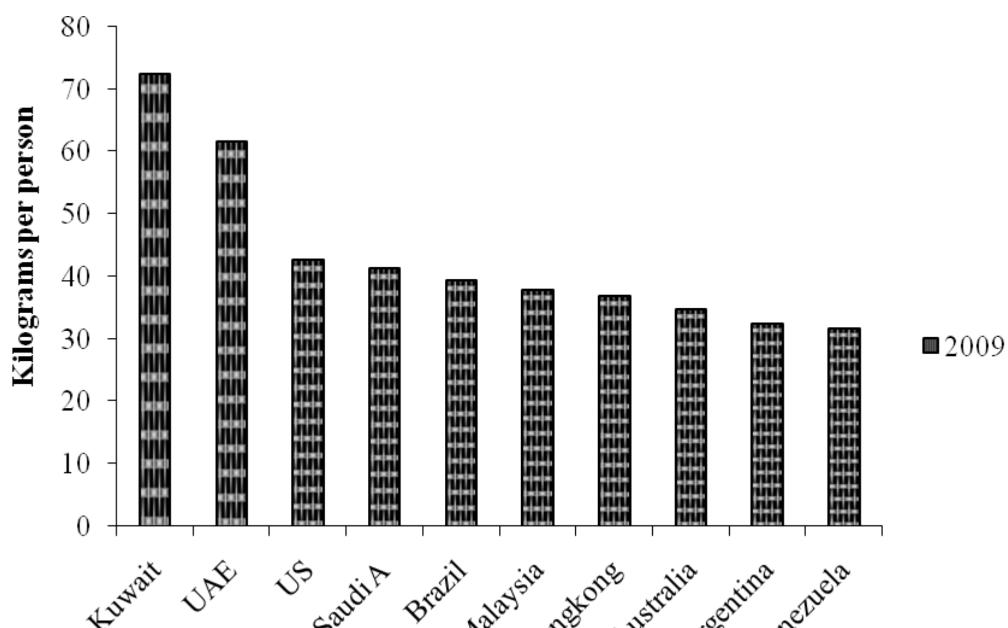

Figure 2.1 Consumption of poultry meat per capita from selected countries (USDA-FAS, 2009).

Figure 2.1 shows the summary of usage of poultry meat per capita from some selected country. The figure shows that Malaysia was the sixth country that highly used poultry meat in food product. The consumption of poultry meat in selected countries has been increasing. This condition occurred because of the increased population size and food demands from poultry meat.

Figure 2.2 shows that the consumption of poultry in Malaysian has been increased from 1999 to 2008. This was due to chicken and duck poultry was easy to breed as compared to other livestock.

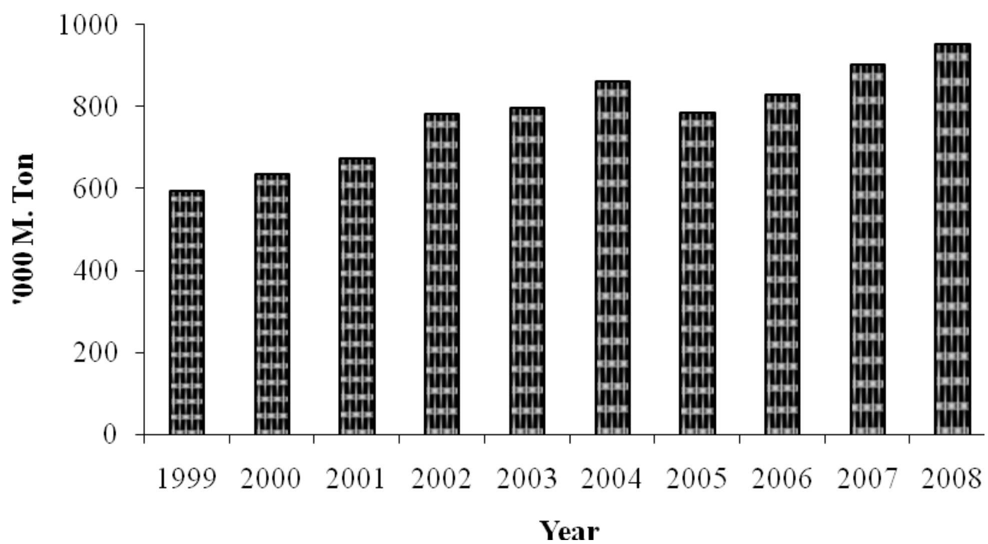

Figure 2.2 Consumption of livestock poultry in Malaysia (DVS, 2009).

2.2 Industries of meat products processed in Malaysia

Malaysia is the largest fifth poultry meat manufacturer among developing countries, with contributes almost 3.9% of poultry meat production in the world. This phenomenon has prompted development of meat based products especially chicken based products. This state is confirmed by the changing economic patterns, rapid development and acceptance changing pattern on chicken products has been increasing among Malaysian population. This statement is supported by Figure 2.3 which shows that poultry intake per capita in Malaysia have increased from 26.18kg in year 1999 to 34.38kg in year 2008.

This rapid development has caused the processed meat products of not only have mastered the food frozen sector but also control the retail sale and fast food restaurant. The increase in fast food chain includes McDonald, Kentucky Fried Chicken, Burger King, Pizza Hut and Kenny Roger Roaster, etc. The processed meat products that have been introduced into the market are burger, sausage, frankfurter, nuggets, chicken balls and others.

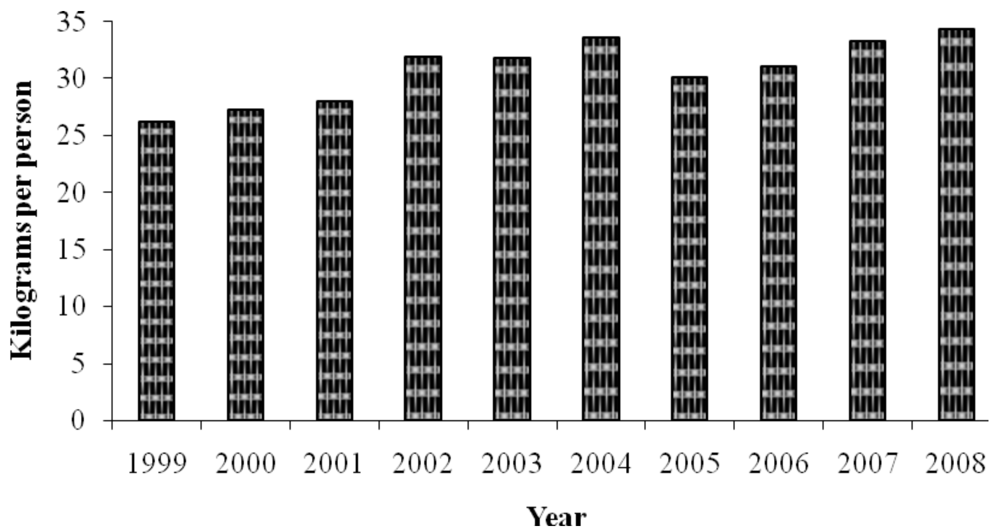

Figure 2.3 Per capita consumption of livestock poultry product (DVS, 2009).

2.3 Poultry meat

Owing to the popularity of poultry meat consumption, which is the second most consumed meat in the world, its transformation into processed products is important to meet the supply of demand for variety and convenient foods. Hence, chicken and duck meat become cheaper as compared to other livestock meat and eventually the demand for chicken and duck meat was higher in Malaysia.

2.4 Duck

There are various types of ducks found in Malaysia, such as Muscovy duck, Local Java duck, Peking duck and mixed duck of male Muscovy with female Peking, which is called the Mule duck (Yeong *et al.*, 1993). Duck meat is normally obtained from the parts of chest and thigh. The meat from thigh usually is darker in colour and more fat content compared to chest meat. The colour of duck meat is darker compared to chicken and turkey meat. Duck has one layer of fat under the skin between the skin and its' flesh (Anon, 2007c).

2.4.1 Peking duck

Figure 2.4 Peking duck.

Peking duck is a type of domestic duck bred for meat and eggs. Peking duck has white feathers, orange beak and legs, while it has flat chest and quite long body. The origin of Peking duck is China but was exported to Europe and North America for breeding as poultry because its' meat contains less fat and the growth rate is faster compared to other ducks. In this day, Peking duck has become the main source of duck meat in the world (Yeong *et al.*, 1993). The texture of Peking duck meat is softer, white in colour and tasty and is favourable in Chinese restaurants. The weight is approximately 4.5 kg for male duck and 4.0 kg for female duck. The meat is around 60.6% (Robin *et al.*, 2004).

Among all the duck meat, Peking duck is the most favoured by consumers. The popularity as a meat producer has spreaded throughout the world. The specialty of Peking duck is attributed to the body which is more compact as compared to other ducks. The feather is white in colour, flesh is smooth like broiler chicken and is not oily and easy to be digested by human. Other specialty of Peking duck is that it can lay 110-125 eggs annually. Hence, the fertility of Peking duck is quite high.

2.4.2 Originality of peking duck

According to its' originality, Peking duck is a wildlife that used to live on China lands, which are Peking and Tien Tsien (Tiongkok). Peking duck possesses large body with white feathers which attracted peoples' interest to hunt for this duck and breed it as a livestock. However, some people collected its' eggs to be consumed. Some eggs were hatched for breeding. The adaptation of Peking duck is high. In the wildlife condition, it can live in water. It can adapt the condition while being bred at home. At the early stage, Peking villagers bred the ducks in pond. After that, they moved the duck into cages. This proved that Peking duck could adapt well in any condition. It is easy to breed Peking's duck. Peking duck is omnivorous, which eat seeds, grasses, potatoes, snails, frogs and fish. This proved that Peking duck could survive longer under different kinds of weathers (Robin *et al.*, 2004).

Peking duck's body is considered big. The body is straight if it is standing. This is why Palmer, one of the American that traveled to China in the year of 1873 assumed the Peking duck as goose. Since then, Palmer took some Peking ducks back to his country. On the way home, a lot of ducks dead. However, there was a male duck and two female ducks that survived. He took the ducks to breeding area when he reached New York. The ducks were recovered from sickness by the treatment given. Out of his expectation, the ducks laid a lot of eggs, which were 100 eggs in four months. Since then, Peking ducks breed well in America (Robin *et al*., 2004).

Various literatures documented that Peking duck in America was no longer pure in species. Breeder had mixed Peking duck with Aylesbury duck, in order to get a new species which grows faster, produces more eggs and possesses better meat texture. In Britain, Peking duck was expanded due to Raymond Harvey's contribution. He obtained the ducks in China since 1872. Meanwhile, he got a duck farm at Cheltenham, Britain. This was the place where he mixed the Peking duck with other ducks in order to produce a better species of duck. Britain's Peking duck is obviously different with America's Peking duck. America's Peking duck does not have straight body, but quite horizontal when it's standing. Its' neck is quite big and long, its' beak is big and long (Robin *et al*., 2004).

2.4.3 Taxonomy and description of peking duck

According to Robin *et al*. (2004) Peking duck was grouped in the Anas genus with the Anas *plathyrynchos* species. Basically, the scientific taxonomy of Peking duck is as follows:

Kingdom	: Animalia
Phylum	: Chordata
Class	: Aves (birds)
Family	: Anatidae
Subfamily	: Anatini
Genus	: Anas
Species	: Anas *plathyrynchos*

A male duck's weight can reach 4.5 kg while female duck's weight can reach 4.0 kg. The following section describes details about the characteristics of Peking duck.

Male duck

- Big and bold head, high eyebrown and contain fur on head.
- Wide, relative short and thick beak. Beak is in light orange colour where the end of the beak is in white colour with black spots.
- Blue colour, wild and protective eyes. Neck is quite long and big and on the straight position, covered with quite long fur.
- Big and round chest.
- Short, strong wings and cover over buttock but not cross over to each other.
- Buttock is 65% longer than neck. It looks quite short because its' tail bend upward and thick.
- Short tail and almost standing but not wide. The feathers on its tail look like cotton and soft.
- Balance, wide and fleshy body.
- Short, strong, red orange leg.
- White nail
- White or cream colour, soft and fine feathers.

Female duck

- Big and bold head, high eyebrown
- Wide, short and thick beak. Beak is in light orange colour where the end of the beak is in white colour with black spots.
- Wild blue eyes covered with striking eye brown.
- Short and big neck.

- Straight standing position.
- Big and round chest and not much bold.
- Short, strong wings and cover over buttock but not cross over to each other.
- Buttock is 65% longer than neck. It looks quite short because its' tail bend upward and thick.
- Short tail and almost standing but not wide. The feathers on its tail look like cotton and soft.
- Balance, wide and fleshy body.
- Short, strong, red orangey leg.
- White nail.

2.5 Mechanically Deboned Duck Meat

Mechanically ground boneless meat is which its bone has removed before going through the grinding process, and the resultant is forced out through a fine pore filter. This will produce a paste-like product due to vigorous breaking process of myofibril protein (Froning, 1981). Composition of mechanically deboned meat showed variation depending on age of bird, cutting method, skin content and protein denatured. Froning (1981) found that using whole chicken would produce higher yield of meat compared to the using parts of body such as neck, back and wings. The yield of mechanically boneless meat was around 55-70% and this value depended on parts of body being used for production.

Basically, mechanically boneless meat contains more fat than protein. This is because backbones part had dissolved protein and eventually increased in lipid content of mechanically boneless tissues (Froning, 1981). Adding skin also increased the fat content of mechanically boneless meat besides enhancing the colour. Satterlee *et al.* (1971) reported that increase in 20% of fat content occurred if 40% of skin was added into mechanically boneless chicken meat. From the view of protein quality, mechanically deboned meat process did not affect the PER (protein efficiency ratio) value for meat. Babji *et al.* (1980) reviewed that protein quality and C-PER value of mechanically boneless chicken was almost same with PER value of rat compared to standard casein value.

2.6 Processed meat product

Processed meat product from meat pieces and particles became output products which were tasty with desirable nice mouthful texture. Structure process included minimizing size of meat particles, followed by mixing and shaping of products (Smith, 1989). Raw material such as tissues, flesh, fat and crumbs were used and this increased the raw material values of meat which was not meat in premium cutting such as steak (Mandigo, 1986). Among value added products that can be produced from reprocessed meat are burger, fillet and bread coating frankfurter, composite products which constitute mixing of meat with other ingredients (vegetables, mushroom, cheese and others), chicken cutlets (Smith, 1985), roast, steak, chop, cube and smoked product (Mandigo, 1986).

Past study showed that the processed meat product had been commercialized and there was an economic potential in production of processed meat products (Smith, 1989). Exponential demands of coated chicken products started since 1982 in United State, where Mc Donalds had started launching Chicken McNuggets product in market (Hunter, 1991). Consumer demands for fast-food, food that is not cooked at home, easy to prepare, time saving and meal in small size has increased (Mandigo, 1986).

Processed meat products possess various advantages. Low value meat (crumbs and old livestock's meat) contained nutritional value which are comparable with premium meat and can be used in processed products. Processed meat products are suitable to be used in products such as beef, sheep, veal, pig, chicken and fish. Particle size, fat content and homogenization of texture could be controlled in production of this product. Non-meat ingredients could be mixed in order to produce more economical formulation (Smith, 1989).

2.6.1 Protein as binding agent in product

The ability of protein to bind food components such as lipid, water and seasoning is vital in the formulation of various foods which are stated in Table 2.1. The ability of protein bind affected stickiness, formation of fiber and film, and development of viscosity (Pomeranz, 1991). Binding was affected by pH and ionic strength characteristic of protein and the physical characteristic of food components such as fat, carbohydrate and lipid, together with changes of mechanical, thermal, chemical and enzymic when food is being produced, stored and processed (Kinsella, 1976).

The phrase 'binding force' was used in production of meat product to explain water and fat holding capacity during cooking and formation of link on surface of meat pieces. Hydrophobic protein reduced surface firmness force and linked lipophilic material such as lipid, emulsions and seasoning.

Table 2.1 Characteristic of protein function in food system (Kinsella and Srinivasan, 1981).

Food system	Characteristic of protein function	Methods of reaction
Meat product, sausage	Water absorption Water linking	Hydrogen bonding HOH Water entrapment
Meat product	Gelation	Formation of protein matrix
Meat product, sausage	Cohesion force	Protein as adhesion
Meat product	Elasticity	Disulphide bonding in gel
Sausage, bologna	Emulsification	Formation and stabilization of fat emulsion
Meat product, sausage	Fat absorption	Free fat linking
Fake meat	Seasoning linking	Permeable, Entrapment, Release of seasoning

The uniform size meat pieces were bound in the matrix which includes tissues and other binding agents (Mawson and Schmidt, 1983). The ability of protein to bind fat was vital in production of bulking agent where fat absorption by protein increased in perpetuation of seasoning and taste in mouth. Fat was absorbed by physically entrapment (Pomeranz, 1991).

2.6.2 Thickening agent

Polysaccharides were used in food as thickening agent, stabilization, gelation and food emulsion (Sanderson, 1981). Adding starch into meat emulsion was more helpful in binding water process compared to limited emulsifying activity (Mittal and Usborne, 1985).

Thickening agents based on starch were chosen accordingly to gelatinizing temperature. Meat protein started to gel at around 57^0C and when does it start to shrink release liquid. Starch as thickening agent should absorb water at this temperature. Potato and tapioca starch are suitable starch which follow the characteristics. When cooking occurred, water should be maintained in product until 70-75^{0}C (Bonnefin, 1991).

2.6.3 Filling and stabilizing agents

Stabilization using polysaccharides occurred in aqueous dispersed phase where continuous phase is water and dispersed phase is solid, liquid or gas. Filling was used define to repair stabilizing characteristic of emulsion, cooking loss, taste and reduce cost by possess bulk to product (Bonnefin, 1991).

2.6.4 Binding agent

Binding agent was added into formulation of meat product to enhance the strength of water and fat binding, cooking yield, taste and reduce formulation cost (Schmidt and Trout, 1984). Binding agents that commonly used in meat product possess two functions, which were binding different sizes of meat pieces and increased in water binding in product (Giese, 1992).

Binding agent that contained protein can function as emulsify agent. Low protein binding agents are able to bind fat physically only (Bonnefin, 1991). Emulsifying process needs decreased of tension force between surfaces in order to form fine liquid droplet (Sanderson, 1981). Basically, polysaccharides and emulsion of fat and oil were used in separation of oil droplet by expanded starch granule (Pomeranz, 1991).

2.6.5 Gel agent

Gel was formed from binding of various molecules to form three dimension networks which can trap water system (Sanderson, 1981). This can be figured as three dimension matrices or protein networks that totally or half binding with polypeptides where water was trapped. This gel contained viscosity, plastic characteristic and high elasticity (Kinsella, 1976).

A few types of polysaccharides can form gel although all polysaccharides contribute to viscosity (Sanderson, 1981). Denaturized gel protein was formed due to heating, the forming of gel protein needs balance between attractive and repulsive force. The forming of gel starts with two stages, which are denaturized of protein that causes polypeptides to arrange continuously followed by gel matrix was formation when attractive force and dynamic balance are suitable.

According Kinsella (1976), when cooling, the broken polypeptides will form to become networks which include covalent and non-covalent interaction, disulphide bonding, hydrogen bonding, ionic force and hydrophobic bonding.

2.6.6 Limitation of binding and bulking agents in processed meat product

Binding and bulking agents were used in meat product to repair quality of products. Sensory characteristic such as texture, juiciness, taste were imparted, water content in product was retained. The yield of final products was able to increase (USDA, 1995).

Level of individually or totally binding and bulking agents that are allowed in processed meat products is on the maximum of 3.5% of the total weight product. Soy protein isolate (ISP) should not exceed 2% for sausage and buckhurst. Binding and bulking agents should not exceed 12% for meat loaf, chicken meatball and salisbury steak and ISP should not exceed 6.8% because of high protein content. Sodium casein that allowed in raw chicken product is on the maximum of 2% of the total weight finished product (USDA, 1995).

2.7 Category of minced meat product

According to Van den Hoven (1987), meat products were grouped according to mince rate. Rough minced products included salami, bratwurst, burger, meat ball and nugget. Fine minced products included frankfurter, hot dog, bologna and mortadella. Production of processed mince products such as emulsion, particle and meat were particularly shaped depending on formation of functioning matrix in products (Schmidt *et al*., 1981).

2.7.1 Characteristic of matrix in meat product

Each class of processed meat product possess different characteristic of matrix. This will give specific texture according to the types of product. This characteristic can be modified according to emulsifying ability, bonding and gelling ability. The main structure of meat emulsion is mixture of meat component as fat emulsion in water, where dispersed phase is fat and continuous phase is water that contained soluble protein (Schmidt *et al*., 1981).

Colloid structure of meat mixture contains two components, which are fat and air that dispersed in another continuous phase which is meat. The dispersed phase consists of fat and air which appeared in three physical forms, which are solid, liquid droplet and gas bubbles. The continuous phase consists of mixture of meat, ice and salt that appears in either paste or gel form, depending on certain parameters such as melting and ionic strength. The different condition of colloids resulted in different non-soluble phase produced, which are emulsion, flocculation and creaming. Emulsion and flocculation are based on the ability of meat protein to emulsify and form stable foam characteristic. Creaming depends on the ability of meat protein to gel (Girard *et al*., 1992).

Emulsion can be defined as liquid and non-soluble particles that scattered in other liquid phase. Stable thermodynamic condition occurred when two phases separated and became two layers, which is called emulsion breaking. In order to stabilize emulsion, one of the phases needs to have active surface agent to decrease the stiffness within surface of the hydrophobic and hydrophilic molecules in meat product. Amphiphilic molecule that acted as active surface agent possesses composite structure that consists of two parts which are water soluble and fat soluble and thus increased in stabilization of emulsion (Girard ***et al.***, 1992).

Protein is a polymer that contains both polar and non-polar group. This protein can adapt conformation and orientation which support surface adsorption (Arnebrant and Nylander, 1988). Water and salt soluble protein can emulsify fat globule by forming protein matrix on fat surface. This characteristic provided stabilization with the addition of reactive group in water-fat inter phase (Schmidt ***et al.***, 1981).

2.7.2 Interaction of muscle protein contributing to the stabilization of meat emulsion structure

The function of muscle protein in the stabilization of emulsion structure was related to various interactions occur in minced meat system, which were protein-water (Regenstein, 1984), protein-lipid (Jones, 1984), and protein-protein interaction (Acton and Dick, 1984). The stability of emulsion structure based on protein lipid interaction in minced meat system including protein membrane inter phase that wrapped fat particles, strengthen of matrix gel in the mixture and psychical characteristic of fat (Jones, 1984).

Each factor helped to stabilize product where little or no fat breaking occur in processed meat product after heat was given. The strength of gel is vital because it guarantees product stabilization and fat holding in product. The strength of gel depends on the strength of ionic content and pH in minced meat system. The variation of melting point and breaking point of fat tissue is related to the physical characteristic of fat that eventually affect the stabilization of minced meat system (Jones, 1984).

2.7.3 Effect of various proteins in meat on the stability of meat emulsion structure

The solubility of connective protein that is low in aqueous solution decreased the ability to emulsify meat. Water holding capacity was destroyed by this protein because of low charge and hydrophilic amino acid. Nutritional value of meat decreased with the stroma protein because of low essential amino acid content (Goll *et al.*, 1977). High amount of collagen increased water holding capacity of meat emulsion. This was because changes of collagen to gelatin increased cooking loss in product (Swatland and Barbut, 1991).

Mechanism of binding between meat pieces consists of interaction of myosin filament extracted from protein with myofilaments on muscles or meat surface. High temperature will open helix of protein to become a long chain that forms hydrogen and ionic cross linking. Salt will make the strongest bonding of myosin. Without salt, the strength of bonds was supported by sarcoplasmic protein. If the concentration of salt increased, sarcoplasmic protein will destroy myosin bonding because of adsorption of denatured sarcoplasmic onto protein molecule (Schmidt *et al.*, 1981).

2.7.4 Types of protein in muscle and function to meat texture

There are up to 50-95% of total organic solids that consist of protein in meat. Muscle protein was divided into three main types according to their solubility in aqueous solvent. Sarcoplasmic protein is globular protein that is not affecting the tenderness of meat. Connective tissues are stroma proteins consisting of collagen which will give bad effect to meat functional characteristic. The decrease in meat tenderness occurs when cross-linking of protein in connective tissues increases (Goll *et al*., 1977).

Myofibrillar protein is the biggest part in muscle and has half solubility in aqueous solution. The highest contributing consumer acceptance to meat and biggest commercial value were due to high water holding capacity (97% of total maximum) and high ability to emulsify (75-90%). The hardness of meat is depending on connective tissues and myofibrillar protein. The quantity of these two substances decides the hardness of meat whether accepted by consumer and measured by equipment. The hardness of actomyosin from myofibrillar was vital in determination of meat tenderness compared to stroma protein.

2.7.5 Solubility protein in meat emulsion

Effect of salt and water

The steps that produce stable meat emulsion directly depending on solubility of salt soluble protein. The adding of sodium chloride to the meat muscle is to dissolve myosin protein by changing it to negative charge with chloride ion at normal pH (Price and Schweigert, 1971). The soluble myosin provides stickiness to minced meat. Water is required in the myosin extraction step. Water need to be added although meat contained up to 75% water. With the presence of sodium chloride, water is a solvent for myosin. Salt helped meat to hold large amount of water (Gillett, 1987).

Effect of pH

pH of meat will affect solubility and water holding capacity of myosin. Pre-rigor meat contained two times of salt soluble protein compared to post-rigor meat because of its' high pH (Saffle and Galbreath, 1964; Trauthman, 1964). At isoelectric point of myosin (pH 5.0 to 5.4), the net charge is zero which caused myocin and actomyosin to be the least soluble. Adding acid directly to meat emulsion destroyed emulsion stability and fat breaking occurred. The less soluble myosin caused collagen to dissolve in acid (Gillett, 1987).

Effect of temperature

The temperature of protein extraction should not be too low (less than -2^{o}C) so that the mixture is not too sticky and temperature should not exceed 7^{o}C so that the solubility of protein is not decreased (Gillett *et al.*, 1977). Animal fat melting point is species dependent. Pork fat melted at 38-47^{o}C, while beef fat which is more non-saturated need higher heat to melt it which is around 41^{o}C-48^{o}C (Acton *et al.*, 1983). The time of cutting (minced) is critical for myosin extraction. Mechanical action increased myosin solubility (Gillett, 1987).

Effect of particle size

Small particle size with increased total surface area will help in protein extraction. In the forming of meat emulsion, blender or minced machine reduced size of meat particles and increased in chemical reaction of surface (Gillett, 1987).