FUNCTIONAL PROPERTIES, CHANGES DURING STORAGE AND APPLICATION OF "DUCKRIMI" (SURIMI-LIKE MATERIAL FROM DUCK MEAT) ON SAUSAGE

ISHAMRI B ISMAIL

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by

ISHAMRI B ISMAIL

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ABSTRAK

Ciri-ciri berfungsi daging itik telah dikaji melalui tiga peringkat. Peringkat pertama daging itik dirawat dengan bilangan basuhan yang berbeza, peringkat kedua daging itik diawet dengan krioprotektan dan peringkat terakhir daging itik dijadikan produk-berasaskan surimi iaitu sosej. Basuhan memberi kesan terhadap penurunan kandungan lemak dan protein secara signifikan. Basuhan empat kali memberikan keputusan terendah bagi kandungan kolesterol dan mioglobin; tetapi meningkatkan pH, ujian lipatan, lembapan terperah dan kapasiti mengikat air; pada masa yang sama menurunkan kekuatan gel sampel. Sampel dirawat dengan dua kali basuhan menunjukkan nilai tertinggi bagi ujian lipatan, kandungan lemak yang rendah dan nilai kecerahan dan keputihan yang terbaik. Satu kajian terhadap keberkesanan beberapa jenis krioprotektan (sukrosa/sorbitol, polidekstosa, maltodekstrin, palatinit, laktitol dan trehalosa) dalam menghalang gangguan aruhan-beku dalam sistem semulajadi aktomiosin surimi itik telah dijalankan. Palatinit hanya dapat menstabilkan miosin dan menghalang penurunan mendadak aktiviti Ca^{2+} ATPase dan kumpulan-kumpulan sulfhidril surimi pada awal bulan penyimpanan. Polidekstrosa merupakan krioprotektan paling berkesan untuk melindungi protein daripada denaturasi dan melambatkan kinetik agregasi protein pada keseluruhan masa penyimpanan beku. Empat formulasi sosej telah dikaji iaitu sosej ditambah polidekstrosa, ditambah BHA, dirawat air dan sosej tidak dirawat. Sosej yang ditambah dengan polidekstrosa mempunyai nilai yang terendah kehilangan memasak dan TBA, tetapi mempunyai aktiviti antimikrob yang tinggi. Sosej yang dirawat dengan BHA

mempunyai ciri-ciri warna yang stabil semasa penyimpanan sejuk. Formulasi sosej yang mengandungi polidekstrosa mempunyai nilai kekerasan, kegaman dan kekunyahan yang tinggi. Tiada perbezaan signifikan dalam komposisi asid amino untuk semua sosej. Keputusan penilaian deria menunjukkan para panel tidak suka sedikit pada bau dan rasa sosej itik. Oleh itu, sampel yang dirawat dengan dua kali basuhan dan diawet dengan polidekstrosa merupakan rawatan paling sesuai dalam menghasilkan sosej daripada daging itik.

FUNCTIONAL PROPERTIES, CHANGES DURING STORAGE AND APPLICATION OF "DUCKRIMI" (SURIMI-LIKE MATERIAL FROM DUCK MEAT) ON SAUSAGE

ABSTRACT

Quality characteristics of duck meat were studied through three stages. In the first stage, duck samples were treated with different number of washing cycles. In the second stage, duck meat was preserved with various types of cryoprotectant and in the final stage, duck meat was developed into surimi-based product i.e. sausage. Washing was found to reduce fat and protein content significantly. The quadruple washing resulted in the lowest cholesterol and myoglobin contents; but higher pH, folding score, expressible moisture and water holding capacity; at the same time reducing the gel strength of the sample. Samples treated with a double washing cycle exhibited the highest folding score, a low fat content and the best lightness and whiteness values. The effectiveness of several cryoprotectants (sucrose/sorbitol, polydextrose, maltodextrin, palatinit, lactitol and trehalose) in preventing freeze-induced disturbances in the systems of natural actomyosin of duck surimi was studied. Palatinit tend to stabilize myosin which prevented a sharp decrease of Ca^{2+} ATPase activity and sulfhydryl groups in surimi during early storage period. However, polydextrose was the most effective cryoprotectant to protect proteins against denaturation and slowing down the kinetics of protein aggregation during the entire storage period. Four formulations of sausage were studied i.e. polydextrose-added, BHA-added, water-treated and untreated sausage. Polydextrose-added sausage had lower cooking losses and TBA values but higher antimicrobial activity. Sausage treated with BHA maintained its color during refrigerated storage. Sausage formulation containing polydextrose was higher in hardness, gumminess and chewiness values. There was no

significant change in amino acid compositions for all the sausages. Sensory evaluation results showed that panelists dislike slightly the odor and taste of duck sausages. Therefore, sample treated with double washing cycle and preserved with polydextrose is the most suitable treatment in producing sausage from duck meat.

Chapter One

Introduction

1.1. Background of study

Surimi (a Japanese commercial name of minced fish) is a Japanese invention. It is minced meat in which all water-soluble proteins in the fish muscle are washed out and, thus, contains only 15–16% insoluble proteins, 75% water and 8–9% freezing stabilizers. The invention of freezing stabilizers was also the main reason for the development of the modern Japanese surimi industry (Trondsen, 1998). In the present study, sucrose and sorbitol were used as a reference. These sugars were acted as a freezing stabilizer (cryoprotector) for stabilization of the surimi quality during long periods of frozen storage (often more than 1 year). The sucrose and sorbitol mixture has become the standard for cryoprotectant in the surimi industry worldwide. The amount of cryoprotectant necessary to stabilize the gel strength of surimi resulted in the sweet taste found in the final consumer products made from surimi (Trondsen, 1998). Nowadays, due to the consumers' increase health awareness, the percentage used in cryoprotectant had reduced to 6% (3% sucrose and 3% sorbitol).

The successful development of the fish surimi process and increasing market share of surimi-based products throughout the world have led to studies aimed at applying surimi technology to the muscle of animal species other than fish which are then called surimi-like material (Antonomanolaki et al., 1999). The characteristics of surimi-like material from poultry meat especially chicken (Babji et al., 1998; Ensoy et al., 2004; Jin et al., 2007; Nowsad et al., 2000a) beef, pork, mutton (McCormick et al., 1993) and also from meat by-products, such as, beef hearts have been studied (Desmond and Kenny, 1998). The study of poultry surimi-like material only focused on chicken.

However, not many researchers attempt to study quality characteristics of duck meat especially evaluating the potential utilization of duck meat as source for surimi-like material called duckrimi. In fact, duck-based products are rarely found in the market today. Some reasons for the lack of acceptance of duck meat by consumers are due to the higher price and lack of tradition consumption, sharp cheesy odor with the fatty odor, ducky like flavor, ducky like odor, higher fat content, less juicy, tougher and less palatable.

Duck production is important in many Asian countries (Tai and Tai, 2001). China ranks first in duck meat production by a wide margin and produces 67% of the duck meat in the world. Almost 30% of poultry meat in China is from ducks. France, Malaysia, Thailand, Vietnam and the United States of America are the leading countries in duck production after China (FAOSTAT, 2009). The largest number of duck meat production in Malaysia was mainly contributed by Perak state i.e. 5,213,998 birds in 2009 (Department-of-Veterinary-Services-Perak-Malaysia, 2009).

Some of the advantages of duck are as follows: they require inexpensive, non-elaborate housing facilities; little attention and less space for rearing compared to chickens; are hardy and resistant to common avian diseases; and feed on a variety of foods (Cagauan et al., 2004). One approach to increase the value of duck meat or other underutilized poultry meat (turkey, quail and spent layer) is to develop technologies for utilizing oversupply of lower-value meat as human food. Duck meat is higher in fat and darker in color than chicken. Spent layer chicken is tough and dry due to its high connective tissue content and it is less preferred by consumers compared to normal chicken. For this reason, underutilized meat could be considered as a source of animal protein for processing new products (Ensoy et al., 2004). One way of salvaging spent-layer meat might be surimi production by washing this meat using a washing solution.

1.2. Objectives of the study

The main objective was to study the functional properties of duckrimi, changes during storage and application of duckrimi on sausage. These include:

i. To study the effect of the number of washing cycles on functional properties of duckrimi.

ii. To determine the most effective cryoprotectant (sucrose/sorbitol; trehalose; polydextrose; maltodextrin; lactitol or palatinit) on preserving gel quality of duckrimi.

iii. To determine the physicochemical properties and sensory acceptable of sausage formulated with duckrimi.

Chapter Two

Literature Review

2.1. Ducks in Malaysia

2.1.1. Duck species in Malaysia

A Khaki Campbell (*Anas Javanica*) is a breed of domesticated duck that originated in England and is kept for its high level of egg production (Wikipedia, 2011e). In Malaysia, the main state which rears khaki campbell ducks are Perlis, Kedah and Pulau Pinang. The northern region of Malaysia has many paddy fields and near to the beaches which make it suitable for the rearing of egg producer ducks; broken rice and sea fishes are the main sources of the protein and energy for this duck (Agronomy, 2010). Khaki Campbell ducks have characteristic brown color, have extremely active habits and show little desire for swimming. These ducks are good layers; they lay as many as 300 or more eggs a year which are fairly large, thick-shelled and weigh 70 to 75 grams each (Department-of-Agriculture, 2011) and they were used in the present study (Figure 2.1).

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Figure 2.1. Khaki Campbell duck

Pekin duck (*Anas platyrhynchos domestica*) is a native of China belonging to the meat type of ducks. It is a good broiler and, duckling is ready for market at 2 or 3 months old (Department-of-Agriculture, 2011). Perak state is a major producer of broiler duck in Malaysia with the production of 4,721,100 birds in 2009 (Department-of-Veterinary-Services-Perak-Malaysia, 2009). Pekin duck external feathers are white sometimes with a yellowish tinge. Adult males and females weigh about 4 kg and 3 kg respectively. In one season, each female will lay about 200 eggs (Wikipedia, 2011f).

Muscovy (*Cairina moschata*) is a group of bird that resembles to chicken and goose. In Malaysia, it is called as “Itik Serati” or “Itik Nila” (Wikipedia, 2011d). Department of Veterinary Services, Kg Paya Jaras Hilir Sungai Buloh Selangor are the only farm that rears Muscovy ducks in Malaysia (Tajudin, 2010). Percentage of carcasses for Muscovy type is around 74% (Kleczek et al., 2006). Male Muscovy is 50% weight than female Muscovy. In this case, it depends on the difference of the growth rate for both male and female Muscovy. Male and female Muscovy ages normally can reach to 12 and 10 weeks, respectively. Muscovy has higher muscle weight meat but lower in fat content (Kleczek et al., 2006).

The White-winged Wood Duck (*Cairina Scutulata*) or known as “Serati Hutan” is a species of dabbling ducks from the genus *Cairina* (Wikipedia, 2011c). This species is highly endangered, with a very small population numbering in the hundreds scattered around South-East Asia, India, Bangladesh and Myanmar. This species live deep in the forest, near pools and marshes, nesting high in the trees. The White-winged Wood Ducks feed mainly at night on seeds, grains, rice, snails and fish. They have white head and neck with black spots. The bill is orange, mottle with black. The wings are tipped with white. The female is smaller than the male (BirdLife-International, 2011).

The Northern Pintail (*Anas acuta*) or called as "Itik Muara" is a slender duck with long neck (Wikipedia, 2011a). The males can be differentiated from the females by their size and color. The males are larger, with brown head, white neck and under parts, a grayish back and sides and long black, pointed central tail feathers. The smaller females have brownish head, grey bill and a slightly pointed tail. This species is common and widespread, often flocking in large groups. They prefer to reside near marshes and ponds. The Northern Pintail grazes on vegetation and the males are more aggressive than the females (Robinson, 2002).

The Shoveler (*Anas clypeata*) or known as "Itik Sudu" is widespread and breeds in the northern areas of Europe and Asia (Wikipedia, 2011b). It migrates to the south during the winter season. They can be found in small flocks. The species is distinguished by its large spatulate bill. The male has a green head, white breast and chestnut belly and flanks. The females are light brown with long broad bill and grey forewing. They flock in open wetlands and feed on plant food, using the bill to strain food from the water. They also eat mollusks and insects in the nesting season. The nest is usually close to water, formed by a shallow depression on the ground and lined with grass and feathers (Johnson, 2000).

2.1.2. Nutritional composition of duck meat

Nutritional composition of duck meat is dependent on their diet. Comparison between the nutritional values for duck, chicken and turkey has been summarized in Table 2.1. Like other meats, duck is an excellent source of high quality protein containing a well-balanced array of amino acids. Duck also contains generous amounts of iron, phosphorus, zinc, copper, selenium, thiamin, riboflavin, niacin, pantothenic acid, Vitamin B6, Vitamin B12, and lesser amounts of Potassium, Magnesium, Vitamin E, Vitamin A, Vitamin C and folic acid (Appendix B). When compared on a lean to lean basis, duck is very similar in nutrient composition to other meats, as can be observed from the data in Tables 2.1. Duck meat contains relatively low levels of fat and calories, and compare favorably, even to chicken and turkey.

Table 2.1. Nutrient composition of raw meat (lean only) from ducks, broilers and turkeys. All amounts are per 100g edible portion

Nutrient	Unit	Duck	Chicken	Turkey
Energy	kcal	135	119	120
Fat	g	5.95	3.08	2.86
Protein	g	18.28	21.39	21.77
Calcium	mg	11	12	14
Iron	mg	2.40	0.89	1.45
Sodium	mg	74	77	70
Selenium	mcg	13.9	15.7	26.5
Vitamin C	mg	5.8	2.3	ND
Niacin	mg	5.30	8.239	4.544
Linoleic acid	g	0.67	0.55	0.64
Saturated fatty a.	g	2.32	0.79	0.95
Mono unsat f. a.	g	1.54	0.90	0.61
Poly unsat f. a.	g	0.75	0.75	0.83
Cholesterol	mg	77	70	65

Note: Data from USDA nutrient database (USDA, 2010b); ND = Not Determined.

2.2. Surimi technology

2.2.1. Surimi processing technology

Invention of surimi technology in poultry meat processing can provide a new approach towards increasing its value and utilization. Surimi technology is an effective method to remove fat, connective tissue, pigment, flavor components and soluble protein. Approaches to improve the quality of poultry surimi can be adopted from the process innovations in fish surimi processing. Figure 2.2 shows the surimi technology flow chart with the basic steps processors use to transform fish into surimi paste and then into imitation seafood. In general, four steps are used in the processing of fish to surimi. This includes: 1) separation of fish flesh, 2) water washing, 3) addition of cryoprotectant and 4) freezing.

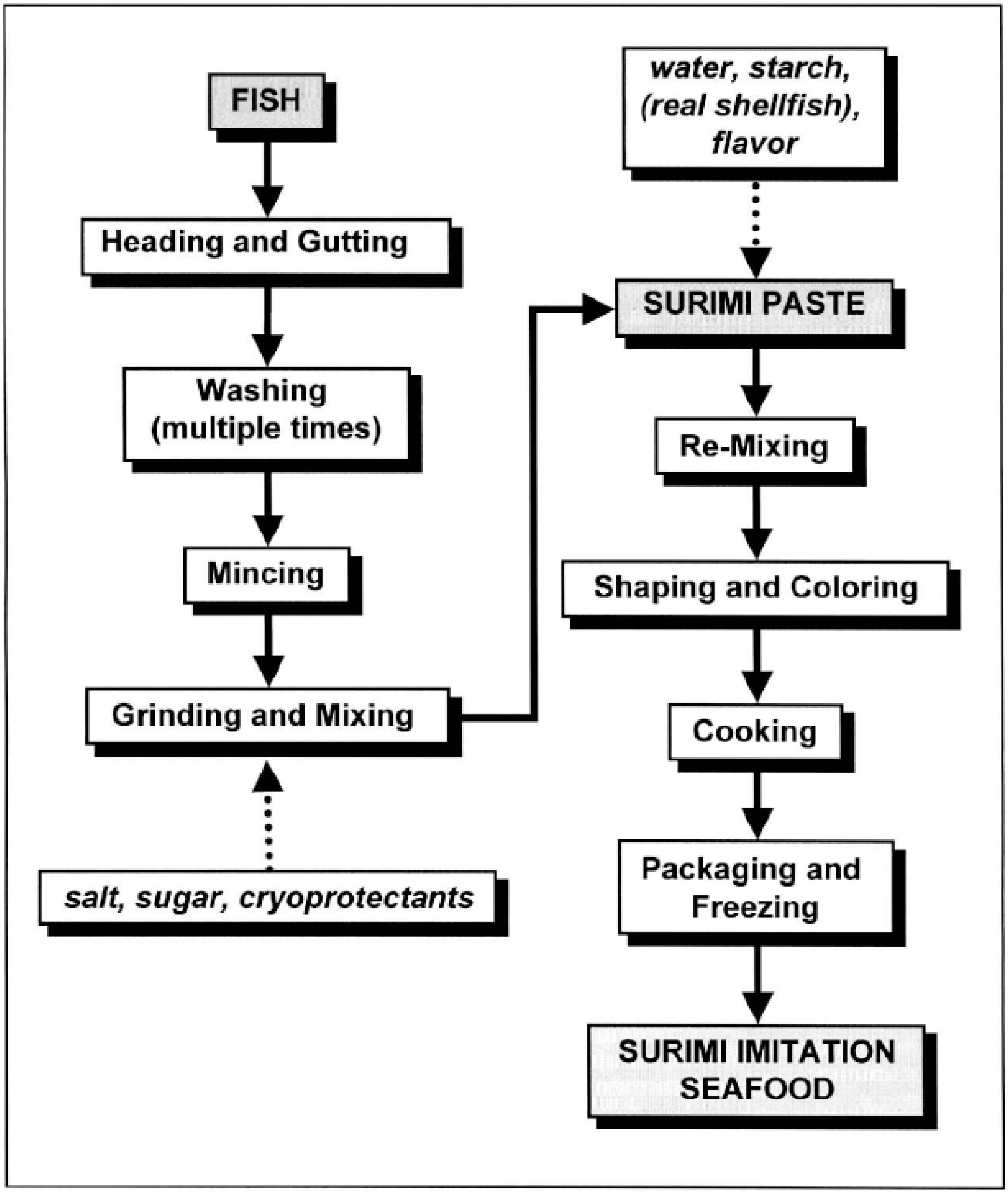

Figure 2.2. Surimi processing technology flow chart. Shows the basic steps processors use to transform fish into surimi paste and then into imitation seafood (Mansfield, 2003).

Fish flesh can be separated from skin and bone by using a mechanical deboning machine. Before deboning, fish should be washed with water to remove contaminants such as pollutant and other unwanted materials. Small fish can be mechanically deboned directly, but for large fish it is usually recommended that fish be gutted and headed before deboned. The minced fish flesh is then washed with chilled water. Usually 3 times washings with the water-to-minced fish ratio of 5:1 is used to remove blood, enzymes, sarcoplasmic protein and fat. The purpose of washing is to improve color and odor and also to increase the gel strength of the surimi. Some of the processors also used carbonate or pyrophosphate solution at the end of the washing treatment.

Cryoprotectant, sugar or polyols, are added to the colorless and odorless minced meat to protect the protein from denaturation during freezing and frozen storage. Earlier, sucrose (10%) was used as a cryoprotectant. However to reduce sweet taste, the amount of sucrose was reduced to 4% with the addition of 4% of sorbitol. Polyphosphate at a concentration of 0.2%-0.3% are added to increase the water holding capacity. The mixture was packed into polyethylene bags, usually about 10 kg for each bag, frozen at -35°C and stored at a constant temperature of -20°C or below. With this condition, surimi can be stored up to one year without any significant changes in quality.

The applications of technology in surimi processing could help to improve the final products of surimi-based products. For instance, centrifugation was used to minimize insoluble protein loss in the washing stage and it was used for dewatering of the washed mince. Centrifugation method was used to separate soluble proteins, bone, skin, connective tissue, cellular membranes, and neutral storage lipids and to reduce water content. Surimi technology can also reduce marginal cost and time compared to the conventional method.

2.2.2. Washing process

Increasing demands for processed poultry white meat have created a need for new ways to process the oversupply of lower value cuts such as: neck, backs, thighs and drumsticks. There is a high potential for utilizing these co-products for the manufacture of surimi-like material as a raw material for use in the preparation of emulsion-type and restructure products. However several constraints have limited the use of mechanically deboned poultry meat in surimi production. The small particle size can lead to poor textural properties in the gel (Antonomanolaki et al., 1999). Higher levels of unsaturated fatty acids in poultry fat result in greater rancidity development (Waheed et al., 2004) and a short storage life for the mechanically deboned poultry meat. Although chicken is considered a white meat, the dark color of mechanically deboned chicken can lower its value.

Most of pigments in mechanically deboned chicken meat are loosely held and can be removed simply by water washing and a centrifugation process. Yang and Froning (1992b) reported that tap water, phosphate buffer solution, sodium bicarbonate solution and sodium chloride solution were effective for the removal of heme pigments. Alkaline washing conditions removed the heme pigments more effectively and increased the lightness of the washed meat. Various wash solutions were studied and a list of researches related to alternative washing solutions are listed in Table 2.2. Results in Table 2.2 reported that, color, gelling quality, water-holding capacity and textural properties were improved after washing. Ensoy et al. (2004) reported that 0.5% sodium bicarbonate solution resulted in a product with the highest pH, lowest fat and lowest pigment concentration, all of which are favorable characteristics in the manufacturing of further processed products.

Table 2.2. Alternative washing solution applied in surimi and surimi-like material

Wash Solution	Sample	Main Results	Reference
Sodium chloride, deionized water	Jonah crab	1. Wash treatment and NaCl concentration significantly affected gelation. Washed samples exhibited significantly higher WHC. Multiple washing steps increased the force to gel deformation. Wash treatment and NaCl concentration affected the color of gels.	Baxter et al. (2008)
Distilled water	Alaska pollock, pork leg, chicken breast	1. Alaska pollock surimi was higher in WHC, lightness, whiteness, breaking force and gel strength compared with pork leg and chicken breast surimi samples. 2. Sensory panels could not distinguish a difference in taste between muscle types and washing times.	Jin et al. (2007)
HCl, NaOH, tap water	Atlantic menhaden	1. Alkaline solubilization processing produced the highest gelling quality only in one washing step but resulted in poorer color than conventional washed surimi.	Pérez-Mateos and Lanier (2006)
Hydrogen peroxide, sodium hypochlorite	Bigeye snapper	1. Oxidizing agent washing directly affected the physicochemical properties of muscle protein and gel strength of bigeye snapper surimi. 2. NaOCl (sodium hypochlorite, 20 ppm) was the most appropriate washing medium in terms of gel property improvement, especially for low-quality fish.	Phatcharat et al. (2006)
Cold water (air floatation wash)	Horse mackerel	1. Air floatation wash loosened the muscle structure and destabilized myofibrillar protein of mince. 2. Suitable air floatation wash improved the gel forming ability of mince by enhancing the removal of water soluble proteins.	Lin et al. (2005)

Table 2.2. (Continued)

Tap water, trisodium phosphate dodecahydrate	Chicken thighs	1. Sensory quality was not adversely affected by trisodium phosphate. 2. The color, smell and overall acceptability scores for the boiled thigh meat were not different between the treated samples and the control ones (washed with water). 3. Only the color, flavor and overall acceptability of thighs dipped in 12% trisodium phosphate were rated significantly lower than the control sample.	Capita et al. (2000)

2.2.3. Cryoprotectant role on surimi

In order to remove pigments and fat from poultry meat, a longer washing time at a higher temperature is required compared to the conditions used for fish surimi processing. Therefore, some of the functional characteristics of the poultry meat proteins such as gel forming ability, hydration capacity and emulsifying capacity may deteriorate during the washing process. Frozen storage is an essential step in surimi manufacture. Frozen storage brings about detrimental changes in the functional properties of surimi protein, such as gel forming ability, water-retention properties, and protein solubility. The loss of functionality is due to the denaturation of protein because freezing increases solute concentration and favors dehydration, both of which contribute to protein denaturation (MacDonald and Lanier, 1991).

The functionality properties of fish surimi protein during frozen storage usually preserved using cryoprotectants, various types of cryoprotectants, such as sucrose, sorbitol and polyphosphates, have been blended with surimi (Okada, 1985). Sucrose and sorbitol improve the gel-forming ability, increase protein solubility and decrease cooking loss (Sych et al., 1991). Sorbitol is combined with sucrose to protect myosin from denaturation (Konno et al., 1997) and enhances the cohesiveness of thermo-induced gels by controlling the cross-linking reactions of myosin during setting (Kimura et al., 1991). A mixture of sucrose and sorbitol has been shown to be an effective cryoprotectant in inhibiting protein denaturation during frozen storage of surimi; however, the excessive sweet taste in the final products has received some criticism (Park et al., 1988). Recently, interest has focused on identifying other cryoprotectants also known as less-sweet sugar with reduced or no sweetness for use in surimi. Lactitol®, Palatinit® and polydextrose, which are less sweet than sucrose/sorbitol, stabilized fish surimi proteins during frozen storage equally as well as the sucrose/sorbitol mixture (Sych et al., 1990b).

Cryoprotectants have been shown to have marked effect on the preservation of the functionality of various warm-blooded animal muscles, such as beef mince (Park et al., 1993), beef heart surimi (Wang and Xiong, 1998) and chicken myofibrillar protein isolates (Trziszka et al., 1991; Uijttenboogaart et al., 1993). Some of the process innovations adopted in fish surimi processing could be transferred to poultry surimi production as a means of improving both the color and protein functionality of the poultry surimi.

2.2.4. Low calorie sweetener

One disadvantage of the commercial cryoprotectant blend used is the high level of sucrose and sorbitol which impart a sweet taste. In addition, today's consumer is conscious of caloric content, and low calorie cryoprotectants in surimi may be preferred. Many studies have been done recently which use cryoprotectants with reduced or no sweetness and calorie content. The cryoprotective effects of lactitol, maltodextrin, palatinit, polydextrose and trehalose have been studied extensively (Carvajal et al., 1999;

Herrera and Mackie, 2004; Sultanbawa and Li-Chan, 1998; Sych et al., 1990a; Zhou et al., 2006).

2.2.4.1. Lactitol

Lactitol (4-O-(ß-D-galactopyranosyl)-D-glucitol) is a polyol and a sweet tasting sugar alcohol derived from lactose by reduction of the glucose moiety of the disaccharide. Lactitol is 0.3-0.4 times as sweet as sucrose, and its nutritional caloric utilization is half that of carbohydrates, with a maximum metabolic energy value of 2 kcal/g (Sultanbawa and Li-Chan, 1998). It is considered a desirable sugar substitute for diabetic patients (Velthuijsen and Blankers, 1991) and has been approved by the FAO/WHO Expert Committee (Anonymous, 1983).

2.2.4.2. Maltodextrin

Maltodextrin (α-1,4) is a polysaccharide that is used as a food additive. It is produced from starch by partial hydrolysis and is usually found as a creamy-white hygroscopic spray dried powder. Maltodextrin is easily digestible, being absorbed as rapidly as glucose, and might be either moderately sweet or almost flavorless. Maltodextrins are classified by DE (dextrose equivalent) and have a DE between 3 to 20 (Wikipedia, 2010b).

2.2.4.3. Palatinit

Palatinit is produced from sucrose and is an equimolar mixture of D-glucosyl-α (1→6) – D glucitol and D-glycosyl-α (1→1) – D – mannitol (Sträter, 1986). Palatinit present several attractive properties including reduced caloric value of approximately 50%, relative sweetness of 0.50 compared to sucrose, essentially non-carcinogenic and well tolerated by diabetics (Ziesenitz and Siebert, 1987). Palatinit has passed a complete toxicological assessment and has been submitted for GRAS status approval in the United States (Sträter, 1986). Its use has been authorized in England and Switzerland since 1983.

2.2.4.4. Polydextrose

Polydextrose is a highly branched polysaccharide prepared by the thermal polymerization of glucose (Park and Lanier, 1987). The use of this nonsweet bulking additive as cryoprotectant in muscle food has been patented. Park et al. (1988) reported that it could substitute sucrose/sorbitol (at the same level, 8% w/w) in surimi without alteration of cryoprotective effects. Polydextrose has been approved by FDA for use in reduced or low caloric foods.

2.2.4.5. Trehalose

Trehalose (D-glucopyranosyl-α (1→1)-D-glucopyranoside) is a non-reducing disaccharide with low caloric value and low sweetness, only 45% of that of sucrose (Hu et al., 2004). It is very stable in properties and can protect biological cells under adverse circumstances (Ren et al., 2001). Trehalose has been found to have protective effect against thermal inactivation of enzymes and its effectiveness was correlated with its large hydration volume (MacDonald et al., 2000).

2.3. Functional properties of surimi

2.3.1. Surimi functional properties

Surimi posses some important functional properties such as gel forming ability and water holding capacity (WHC) due to its content of myofibrillar protein that plays the most critical role during meat processing. They are responsible for formation of gel and emulsions, which is essential to the stabilization of comminuted and restructured meat products (Xiong, 1997; Zhou et al., 2006). The physicochemical state of myofibrillar proteins affects the functionality of meat system and plays a direct role in determining the quality and value of processed meat (Li and Wick, 2001).

Some functional properties requirements in surimi production are gelation, emulsification and water holding capacity. Gelation properties of surimi can be affected by several factors; 1) extent of denaturation and premature aggregation of the myofibrillar proteins before manufacturing; 2) species and habitat of raw material which determine the heat stability of the myofibrillar protein; 3) activity of proteolytic enzymes which will cleave proteins and disrupt the gel; 4) activity of endogenous or added protein oxidant as well as cross linking enzymes which contribute to protein cross-linking and; 5) relative concentration of myofibrillar versus sarcoplasmic and/or stroma protein (Park, 2005). While, emulsification and water holding capacity of surimi can be affected by temperature, sufficient energy input, undenatured/denatured protein, droplet surface area, pH, ionic strength, presence of other components food, lipid and salt, and condition of storage (Smith, 2001; Zayas, 1997).

2.3.2. Actomyosin

Actomyosin is myofibrillar proteins of surimi and these myofibrillar proteins are solubilized by salt (salt soluble proteins). The gel-forming ability measured by the water-binding capacity of the comminuted tissue (protein solubilization) and gel strength is determined by the level of functional actomyosin (Lee, 1994). The level of functional actomyosin, measured as extractable actomyosin or ATPase activity, increases with an increase in the number of washing cycles and decreases as the freshness of the fish decreases; such a decrease in extractable actomyosin is caused by tissue autolysis, which is proteolytic breakdown of myofibrillar protein by catheptic protease. The proteolytic breakdown increases with extended storage (Tamato, 1971). The quality of surimi during frozen storage is affected by storage temperature, storage period, the level of remaining moisture, the type and level of cryoprotectants used, and remaining inorganic salts (Lee, 1994; Tamato, 1971).

However, when the surimi is stored at higher temperatures, the gel-forming ability gradually decreases; this is attributed to a decrease in extractable actomyosin subsequent to freeze denaturation of proteins. Temperature fluctuation during short-term transportation does not significantly reduce surimi quality. However, extended periods of temperature fluctuation (more than three weeks) do cause significant loss in quality (Iwata et al., 1971).

Elasticity and resilience of surimi gel increase with an increase in the concentration of actomyosin, but decrease with an increase in the concentration of water-soluble (sarcoplasmic) proteins. The presence of water-soluble proteins retards gel setting by interfering with the actomyosin cross-linking process. A mechanism was proposed whereby water-soluble proteins bind actomyosin, making it less available for the cross-linking process (Kim et al., 1996).

2.3.3. ATPase activity

Adenosine triphosphatase (ATPase) activity has been widely used as an index for detecting denaturation of myofibrillar protein (Ooizumi et al., 1981). Factors that cause denaturation or degradation of the protein can affect ATPase activities. Such activities have been widely used to monitor postmortem changes during iced or frozen storage (Kamal et al., 1991; MacDonald and Lanier, 1994). Myofibrillar proteins are susceptible to degradation by lysosomal enzymes and calcium-activated neutral proteinases (Quali and Valin, 1981). Therefore, degradation of myofibrillar proteins can be indirectly measured by changes in ATPase activity. This makes measure of ATPase activity useful for quality assessment of muscle (Kamal et al., 1991; Ko et al., 1991; MacDonald and Lanier, 1994; Tachibana et al., 1993).

Denaturation of fish myosin has been studied by using Ca-ATPase inactivation (Kawashima et al., 1973). As ATPase activity reflects important information on the biochemical properties of fish muscle protein, it can be used as the index of the quality of surimi (Gao et al., 2006). Generally, Ca2+-ATPase can be used as an indicator of the integrity of the myosin molecule. Mg2+–Ca2+-ATPase activity can be used as an indicator of the integrity of the actin–myosin complex (Benjakul et al., 1997). While, Mg2+-ATPase has been used to indicate the integrity of actin (Azuma and Konno, 1998).

Myosin is one of the two major protein constituents responsible for contraction of muscle. In muscle cells, myosin is arranged in long filaments called thick filaments that lie parallel to the microfilaments of actin. In muscle contraction, filaments of actin alternately chemically link and unlink with those of myosin in a creeping or sliding action. The energy for this reaction is supplied by adenosine triphosphatase (Encyclopedia, 2007).

2.3.4. Sulfhydryl group

Sulfur is found mainly in proteins in the form of sulfhydryl groups or disulfide groups. Like oxygen, sulfur typically has a valence of 2, although it can also have a valence of 6, as in sulfuric acid. Sulfur is found in certain amino acids and proteins in the form of sulfhydryl groups (symbolized as -SH). Two sulfhydryl groups can interact to form a disulfide group (symbolized as -S-S-) (Anonymous, 2007).

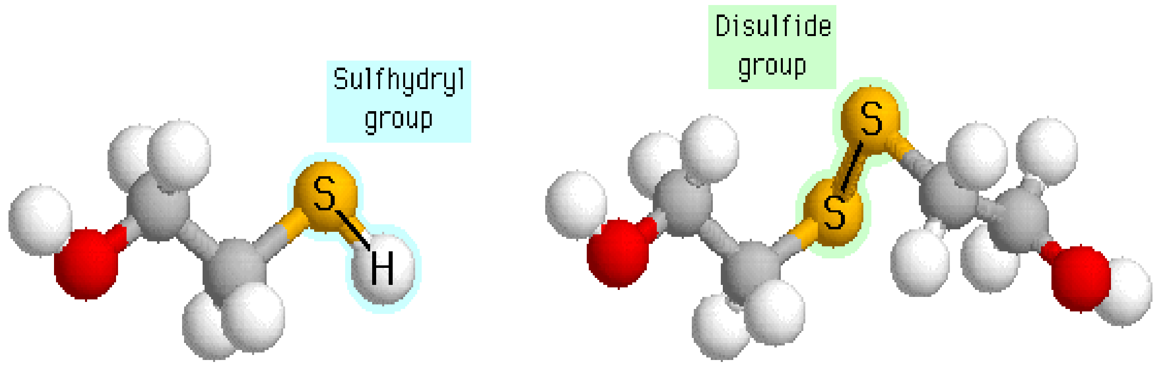

Figure 2.3. Illustrates two molecules; one with a sulfhydryl group and one with a disulfide group (Anonymous, 2007).

Sulfhydryl groups are considered to be the most reactive functional groups in proteins (Sultanbawa and Li-Chan, 2001). Sulfhydryl groups in fish muscle proteins were easily oxidized to disulfide groups during iced or frozen storage, or freeze–thawing process, hence resulting in a decrease in surface or total sulfhydryl contents (Benjakul et al., 1997; Benjakul et al., 2003a; Sultanbawa and Li-Chan, 2001).

Formaldehyde formation could favor the oxidation of sulfhydryl groups and the masking of sulfhydryl groups by protein aggregate might also cause the decrease in free sulfhydryl groups available for determination (Benjakul et al., 2003a). The conformational changes of myosin molecules might cause the reactive sulfhydryl groups to be exposed, resulting in the increase of disulfide bond through oxidation. Myosin (SH_1 and SH_2) plays an important role in ATPase activity and the oxidation of these groups caused the decrease in Ca2+-ATPase activity (Benjakul et al., 2003a). Furthermore, sulfhydryl groups located in other portions of myosin also contributed to oxidation (Sompongse et al., 1996), resulting in the loss of Ca2+-ATPase activity (Benjakul et al., 2003a).

2.4. Duck surimi-like material

2.4.1. Surimi-like material from poultry meat

Surimi production is not only from fish raw material but also there has been considerable interest in manufacturing surimi-like materials from species other than fish (Antonomanolaki et al., 1999). Some of the previous process adopted in fish surimi processing may be applied to poultry surimi production as a means to produce good functionality of gel protein surimi-like material. However, most of the previous studies of poultry surimi-like material only focused on chicken meat (Babji and Gna, 1994; Babji et al., 1995; Jin et al., 2009; Nowsad et al., 2000a; Nowsad et al., 2000b; Yang and Froning, 1992b). Currently, there has been limited research concerning the gel properties of surimi-like material made from non-chicken poultry meat such as duck, turkey and quail.

Babji et al. (1995) reported that, surimi-like material made from chicken showed the highest yield as high as 70.5% and maximum gel strength among other surimi-type materials (beef, beef heart, tilapia, sheep meat, pork etc.). From that study it is evident that poultry has potential as low cost protein based raw material with high functionality property compared to other types of materials.

Studies related with poultry surimi-like material are presented in Table 2.3. However, most of the results used chicken as a raw ingredient. The limitation of using other poultry meat such as duck, turkey and quail could be due to the fat content, high heme pigment and high collagen content. The high fat content, the more heme pigment and the high concentration of collagen, cause several problems to produce surimi-like material.

Table 2.3. Research on poultry surimi-like material

Raw material	Main Results	Reference
Spent layer hens with Alaska pollock and Golden threadfin bream	1. Crude fat and carbohydrate were not significantly different among the samples during storage periods. 2. The pH steadily increased until 2 weeks of storage. Thereafter, the pH decreased in all samples.	Jin et al. (2009)
Washed mechanically recovered chicken meat	1. Washed mechanically recovered poultry meat with the addition of microbial transglutaminase showed a higher water-binding capacity. 2. The protein preparation with the enzyme added had significantly higher values of the moduli of elasticity.	Stangierski et al. (2008)
Chicken breast, pork leg and Alaska pollock	1. Moisture, crude protein and crude fat were significantly lower in chicken breast surimi. 2. Chicken breast surimi samples showed lower lightness (L*). 3. Myoglobin content was lower in chicken breast surimi samples.	Jin et al. (2007)
Spent layer (chicken)	1. Washing reduced protein, fat, cholesterol and ash contents of spent layer surimi. 2. Collagen and myofibrillar proteins of spent layer surimi increased after washing 3. A cryoprotectant mixture of 2% sucrose+ 2% sorbitol+0.3% sodium pyrophosphate resulted in higher water-holding capacity. 4. All washing solutions increased lightness and decreased redness of spent layer surimi.	Ensoy et al. (2004)
Spent hens	1. Textural quality parameters (gel strength, breaking strength, deformation, protein solubility, expressible moisture, cooking yield, folding test, drip-loss, and sensory scores) were decreased in both unwashed and washed mince, mostly during the early stages of storage.	Nowsad et al. (2000a)

Table 2.3. (Continued)

	2. Washed mince showed significantly better textural properties than unwashed mince. 3. Washing protected the gel quality of the hen mince from degradation during frozen storage. 4. Cryoprotectants could not protect the gel strength or breaking strength, but deformation was slightly improved. Water-retention properties were protected and folding test and sensory scores were well preserved in the mince with added cryoprotectant. 5. Cryoprotectants had a beneficial effect on frozen, stored spent hen surimi to protect the elasticity and cohesiveness of the gel.

2.4.2. Potential benefit in using poultry meat in surimi processing

In recent years, there has been an increased demand for fresh or processed poultry products in the market due to their lower fat and saturated fatty acid contents compared to those of red meat products (Ensoy et al., 2004). Interest in producing poultry surimi has been stimulated by a desire to value-add or make better use of raw material ingredients for further processing. The potential benefits of using poultry surimi in processed meats manufacture include lower fat content, reduced risk of rancidity development and microbial spoilage, bland-tasting raw material to which any flavor can be added, almost colorless raw material for incorporation into a wide range of products, improved rheological properties compared with other manufacturing meats and a base raw material that can be used as the major component of products, therefore providing a broader product range than is possible from other processed meats (Jiang and Kurth, 1995).

Poultry products' possession of good animal protein quality accounts for a large percentage of marketing, due to that reason interest has been directed toward developing different methods and products for recovery of protein from underutilized meat sources. Mechanical deboning is one way that enables more efficient utilization of residual parts of poultry. However, due to high pigment and fat contents that limit the use of mechanically deboned meat in low-fat and low-pigment meat products, a surimi-like process as an alternative technology has been applied to mechanically deboned chicken meat (Yang and Froning, 1992a).

However, this study of poultry surimi-like material only focused on chicken. Currently, there is limited research of surimi-like material made from non-chicken poultry meat such as duck, turkey and quail. By applying surimi technology, there is a potential opportunity for low-value manufacturing of poultry meat (duck, turkey and quail) with limited markets to be processed to a higher value poultry-meat protein source.

2.4.3. Advantages and disadvantages of duck meat in surimi processing

Duck is a low-value poultry meat that has the potential to be used as a new source of surimi-like material. Some of the advantages of duck are as follows: they require inexpensive, non-elaborate housing facilities; little attention and less space for rearing compared to chickens; are hardy and resistant to common avian diseases; and feed on a variety of foods (Cagauan et al., 2004).

Duck production is important in many Asian countries (Tai and Tai, 2001). Figure 2.4 shows the changes in world duck production over the last two decades. From this figure we can see the importance of Asia in duck production. Globally, production has increased in this period by 260% and this growth has been driven by China (440%). Growth in the rest of the world is only 116%. China ranks first in duck meat production by a wide margin and produces 67% of the duck meat in the world. Almost 30% of poultry meat in China is from ducks. France, Malaysia, Thailand, Vietnam and United

States of America are the leading countries in duck production after China (FAOSTAT, 2009). Today, more than two thirds of ducks are produced in China and so it is inevitable that what happens or does not happen in China will have a profound impact on the world of duck production.

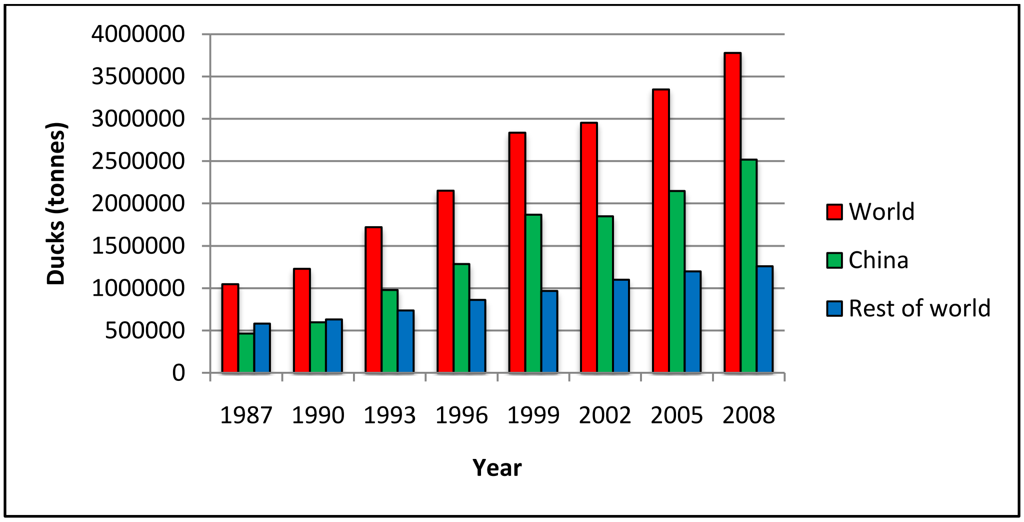

Figure 2.4. Change in world duck production (FAOSTAT, 2009)

Similar to chicken meat, duck meat is rich in polyunsaturated fatty acids (Baeza, 1995). However, unlike chicken meat, duck meat is red. Duck muscles contain mainly red muscle fibers (between 70 and 90% in the breast). Zanusso et al. (2003) reported that breast muscle from overfed ducks is higher in lipid and water levels because overfeeding significantly increases lipid levels in duck meat. Muscle from the overfed ducks was paler in color and exhibited greater yellowness and cooking loss values. Juiciness was judged to be lower and flavor to be more pronounced in overfed ducks (Chartrin et al., 2006). Genotype exerted a higher effect on the sensory quality of breast muscle than did feeding levels. Increasing lipid levels in breast muscle increased lightness, yellowness, cooking loss, tenderness and flavor (Chartrin et al., 2006). However, breast meat color and tenderness were mainly influenced by genotype.

Not many researchers attempt to study quality characteristics of duck meat, and there are few published studies evaluating duck surimi. Table 2.4 shows some studies of duck meat applications that have been reported in the literature. In fact, duck-based products are rarely found in the market today. Some reasons for the lack of acceptance of duck meat by consumers are due to higher price and lack of tradition for consumption (Bernacki et al., 2008), sharp cheesy odor with the fatty odor (Soncin et al., 2007), ducky like flavor (Liu et al., 2007), ducky like odor (Soncin et al., 2007), higher fat content (Bhattacharyya et al., 2007; Biswas et al., 2006; Plavnik et al., 1982) less juicy, tougher and less palatable (Biswas et al., 2006)

Table 2.4. Studies related to duck meat

Sample	Main objective	Reference
Duck meat sausages	To compare properties of duck meat sausages supplemented with different cereal flour including rice, wheat, corn, millet and barley.	Yang et al. (2009)
Sausage from spent duck	To compare the quality of chicken and duck sausages (in natural and artificial casings) prepared from broiler, spent hen and duck.	Bhattacharyya et al. (2007)
Nanjing cooked duck	To examine the effects of different processes on the changes of taste compounds in Nanjing cooked duck.	Liu et al. (2007)
Raw duck meat	To estimate the volatile compounds developed at room temperature by gas chromatography-mass spectrometry (GC-MS) and extracted by solid-phase microextraction (SPME) from the raw meat of pork, duck and goose.	Soncin et al. (2007)
Duck patties	To compare and assess the quality of chicken and duck patties prepared from broiler, spent hen and duck meat.	Biswas et al. (2006)