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Surimi-like Material from Poultry Meat and its Potential as a Surimi Replacer

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ABSTRACT
Invention of surimi technology in poultry meat processing can provide a new approach toward 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. Research has shown that cryoprotectants have a marked effect on the preservation of the functionality of poultry myofibrillar protein. As poultry meat possesses good animal protein quality as well as lower fat and saturated fatty acid contents than those of red meat, there is a higher potential of poultry meat to be a surimi replacer. However, further studies of non-chicken poultry surimi (duck, turkey and quail) are necessary in the future due to the limited information available on the use of these types of meat as surimi replacers.

Key words: Surimi, surimi-like material, washing treatment, cryoprotectant, poultry

INTRODUCTION
Surimi, a Japanese invention, is the Japanese commercial name for minced fish. To make surimi, fish is minced and all water-soluble proteins in the fish muscle are washed out. The final product contains only 15-16% insoluble proteins, 75% water and 8-9% freezing stabilizers. The invention of freezing stabilizers enabled the development of the modern Japanese surimi industry (Trondsen, 1998). At the end of the 1950s, sugar and sorbitol were used as a freezing stabilizer (cryoprotector) for stabilization of the surimi quality during long periods of frozen storage (often more than 1 year). The sugar and sorbitol mixture has become the standard cryoprotectant in the surimi industry worldwide. The amount of cryoprotectant necessary to stabilize the gel strength of surimi results in the sweet taste found in the final consumer products made from surimi (Trondsen, 1998). Nowadays, due to consumers' increased health awareness, the percentage of sugar used in the cryoprotectant has been 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 the surimi technology to the muscle of animal species other than fish, called surimi-like material (Antonomanolaki *et al.*, 1999). The characteristics of surimi-like material from poultry meat (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).

However, the studies of poultry surimi-like material have only focused on chicken. Currently, there is limited research concerning the gel properties of surimi-like material made from non-chicken poultry meat such as duck, turkey and quail. The main question to be answered is, does poultry meat have the potential to be developed into surimi? Thus, the use of poultry for producing surimi must be examined.

Washing treatment: 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 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). High 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 the pigments in mechanically deboned chicken meat are loosely held and can be removed simply by water washing and a centrifugation process. Yang and Froning (1992) 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 studies related to alternative washing solutions is shown in Table 1. 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.

Centrifugation functioned by separating on the basis of density and solubility differences (Kristinsson *et al*., 2005). The centrifugation method was used to separate soluble proteins, bone, skin, connective tissue, cellular membranes and neutral storage lipids as well as to reduce water content. This process reduced the pigment content to an acceptable level in the mechanically deboned poultry meat. The fat content was reduced from 14.5% in the unwashed, deboned chicken to 0.8% after centrifugation (Yang and Froning, 1992).

Poultry surimi-like material: Although, surimi production is typically from fish raw material, there also has been considerable interest in manufacturing surimi-like materials from species other than fish (Antonomanolaki *et al*., 1999; Nurkhoeriyati *et al*., 2010). Some of the previous process adopted in fish surimi processing may be applied to poultry surimi production as a means to produce gel protein that functions as surimi-like material. However, most of the previous studies of poultry surimi-like material only focused on chicken meat (Babji and Kee, 1994; Babji *et al*., 1995; Jin *et al*., 2009; Nowsad *et al*., 2000a, b; Yang and Froning, 1992). 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 the maximum gel strength among other surimi-type materials (e.g., beef, beef heart, tilapia, sheep meat, or pork). From that study, it is evident that poultry has potential as a low-cost, protein-based raw material with high functionality properties compared to other types of materials.

Table 1: Alternative washing solution applied to surimi and surimi-like material

Wash solution	Sample	Main results	Reference
Cold water	Spent duck	• Quadruple washing exhibited a significantly higher pH, folding score, expressible moisture and WHC but reduced the gel strength of the duck meat • Sample treated with a double washing cycle exhibited the highest folding score, a low fat content and the best lightness and whiteness values	Ismail *et al.* (2010)
Sodium chloride, deionized water	Jonah crab	• 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 and Skonberg (2008)
Distilled water	Alaska pollock, pork leg, chicken breast	• Alaska pollock surimi was higher in WHC, lightness, whiteness, breaking force and gel strength compared with pork leg and chicken breast surimi samples • 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	• Alkaline solubilization processing produced the highest gelling quality only in one washing step but resulted in poorer color than conventional washed surimi	Perez-Mateos and Lanier (2006)
Hydrogen peroxide, sodium hypochlorite	Bigeye snapper	• Oxidizing agent washing directly affected the physicochemical properties of muscle protein and gel strength of bigeye snapper surimi • 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	• Air floatation wash loosened the muscle structure and destabilized myofibrillar protein of mince • Suitable air floatation wash improved the gel forming ability of mince by enhancing the removal of water soluble proteins • Excess air floatation wash weakened gel forming ability by decreasing the total sulfhydryls content and/or exposing the protein to air/water interface	Lin *et al.* (2005)
Tap water, trisodium phosphate dodecahydrate	Chicken thighs	• Sensory quality was not adversely affected by trisodium phosphate • 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) • 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)
Sodium chloride	Chicken breast and thigh	• Washed mince showed significantly better textural properties than unwashed mince. Washing protected the gel quality of the hen mince from degradation during frozen storage	Nowsad *et al.* (2000a)

Studies related with poultry surimi-like material are shown in Table 2. The high fat content, the high heme pigmentation and the high concentration of collagen cause several problems in the production of surimi-like material.

Table 2: Results of research on poultry surimi-like material

Raw material	Main results	Reference
Spent layer hens with Alaska pollock and Golden threadfin bream	• Crude fat and carbohydrate were not significantly different among the samples during storage periods • 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	• Washed mechanically recovered poultry meat with the addition of microbial transglutaminase showed a higher water-binding capacity • The protein preparation with the enzyme added had significantly higher values of the moduli of elasticity	Stangierski *et al.* (2008)
Chicken breast, pog leg and Alaska pollock	• Moisture, crude protein and crude fat were significantly lower in chicken breast surimi • Chicken breast surimi samples showed lower lightness (L*) • Myoglobin content was lower in chicken breast surimi samples	Jin *et al.* (2007)
Spent layer (chicken)	• Washing reduced protein, fat, cholesterol and ash contents of spent layer surimi • Collagen and myofibrillar proteins of spent layer surimi increased after washing • A cryoprotectant mixture of 2% sucrose+ 2% sorbitol+0.3% sodium pyrophosphate resulted in higher water-holding capacity • All washing solutions increased lightness and decreased redness of spent layer surimi	Ensoy *et al.* (2004)
Spent hens	• 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 • Washed mince showed significantly better textural properties than unwashed mince • Washing protected the gel quality of the hen mince from degradation during frozen storage • 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 • Cryoprotectants had a beneficial effect on frozen, stored spent hen surimi to protect the elasticity and cohesiveness of the gel	Nowsad *et al.* (2000a)
Spent hen and broiler	• Broiler mince was lighter and less red in color, higher in protein and lower in moisture, lipid and collagen than spent hen • Gel strength and breaking strength were higher in spent hen surimi compared to broiler surimi under similar gelation conditions • Gel elasticity, springiness and water retention properties were almost identical in both surimis • Gel quality was markedly deteriorated in spent hen surimi but not so in broiler surimi after 8 weeks frozen-storage • Cryoprotectant increased the gel strength of fresh surimi (non-frozen, 0 week storage) from both hen and broiler; they were more effective in broiler surimi than hen surimi in protecting the functional quality of gel	Nowsad *et al.* (2000b)
Spent hen	• Spent hen mince washed with 0.1% NaCl was lighter and less red in color and higher in collagen, gel strength, water-holding ability and cooking yield than unwashed mince • Sucrose (4%), sorbitol (4%) and Na-tripolyphosphate (0.2%) improved the gel quality of nonfrozen mince	Nowsad *et al.* (2000c)
Chicken, beef, pork, beef by-product	• Chicken surimi has the highest yield of 70.5% • Washing resulted in the loss of redness in red meat tissue with increase in lightness	Babji *et al.* (1995)

Table 2: Continued

Raw material	Main results	Reference
Spent hens, deboned broiler	• Grinding and three washings reduced the sarcoplasmic proteins but increased extractable salt soluble proteins, pH and WHC • Grinding and three washings increased the L* and a* value but reduced the b* value • Washing produced a desirable gel in both broiler chicken and spent hen compared to the original raw meat	Babji and Kee (1994)
Mechanically deboned chicken	• Washed with tap water, 0.5% sodium bicarbonate, sodium phosphate buffer (pH 7.2 ionic strength 0.1), or 0.1 M sodium chloride had increase gel strength compared to unwashed MDCM and also affected lightness and had a slight influence on WHC and textural properties • Scanning electron microscope revealed that the washed meat showed a fibrous protein network structure resulting from protein gelation	Yang and Froning (1992)

Approaches to Improve the quality of poultry surimi-like material: 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).

To protect the functionality of fish surimi protein during frozen storage, various 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 with reduced or no sweetness for use in surimi (Nopianti *et al.*, 2010). 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 (Uijttenboogaart *et al.*, 1993). Table 3 shows some types of cryoprotectants and the results of their use in surimi. 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.

Table 3: Types of cryoprotectant in surimi and surimi-like material

Cryoprotectant	Sample	Main results	Reference
Trehalose, sodium lactate, sucrose/sorbitol (final concentration 8%)	Tilapia	• Trehalose and sodium lactate effectively prevented the protein denaturation of mince during frozen storage at -18°C for 24 weeks • Trehalose appeared to achieve better cryoprotection than the commercial blend (sucrose/sorbitol, 1:1) • Trehalose and sodium lactate can be used as alternative cryoprotectants in surimi due to their low sweetness and caloric value	Zhou *et al.* (2006)
Polydextrose, lactitol, glucose syrup, sucrose/sorbitol [1:1] (final concentration 8%)	Rainbow trout	• Cryoprotectants prevented drastic decreases in ATPase activity as well as rapid exposure of hydrophobic and sulfhydryl groups on the protein surface of surimi • Cryoprotectants preserved the structural stability of myosin to some extent and slowed down the exposure of buried hydrophobic residues on the protein surface.	Herrera and Mackie (2004)
Sucrose/sorbitol (final concentration	Spent hens	• Sucrose and sorbitol did not protect the gel strength of the stored mince but prevented the 8%, 1:1) gel from becoming tough and rubbery by effectively protecting their water-binding properties • Sucrose and sorbitol maintained folding test and sensory scores of the gel during storage	Nowsad *et al.* (2000a)
Maltodextrins, sucrose, sucrose/sorbitol (final concentration 8%)	Alaska pollock	• All maltodextrins with varying mean molecular weight (MW) indicated good cryoprotection at -20°C isothermal storage but poor cryoprotection by higher MW at higher isothermal storage temperatures	Carvajal *et al.* (1999)
Lactitol, Litesse ™, sucrose, sorbitol (final concentration 4-12%)	Ling cod	• Cryoprotectant blends at levels ranging from 4-12% were all effective in ensuring good gel formation for 4 months in frozen storage at -18°C • Sucrose, sorbitol, Litesse™ and lactitol at a ratio of 1:1:1:1 offered advantages of reduction in sweetness and cost	Sultanbawa and Li-Chan (1998)
Sucrose/sorbitol (final concentration 8%, 1:1)	Beef heart	• Cryoprotectants (sucrose and sorbitol) protected surimi against protein denaturation but enhanced lipid and protein oxidation	Wang *et al.* (1997)
Sucrose/sorbitol (final concentration 8%, 1:1)	Broiler	• Sucrose/sorbitol showed some protection of gel forming ability of frozen samples • Sucrose/sorbitol with tripolyphosphate gave stronger gels after freezing at -25°C for 2-4 days	Kijowski and Ian- Richardson (1996)
Lactitol, palatinit, polydextrose ®, sucrose/sorbitol (final concentration 8%)	Cod	• Palatinit ®, lactitol and polydextrose ® stabilized surimi proteins equally as well as the sucrose/sorbitol mixture did	Sych *et al.* (1990a)

Potential benefits 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 materials 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).

Because poultry products' possession of good animal protein quality accounts for a large percentage of marketing, 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, 1992).

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 poultry meat (duck, turkey and quail) with limited markets to be processed to a higher value poultry-meat protein source.

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*., 2000).

Duck production is important in many Asian countries (Tai and Tai, 2001). Figure 1 shows the changes in world duck production over the last two decades. 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 the United States of America are the leading countries in duck production after China (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

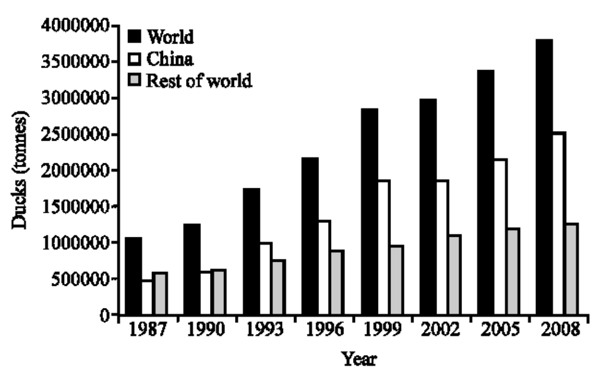

Fig. 1: Change in world duck production (FAOSTAT, 2009)

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 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 shown in Table 5.

Table 4: Studies related to duck meat

Sample	Main objective	Reference
Low-fat duck sausage	• To determine the effect of washing processes and addition of palm oil (0, 3 and 6%) on the composition of duck sausage	Huda *et al*. (2010)
Surimi-like material	• Duck meat utilization and the application of surimi-like material in highlyprocessed meat products (review paper)	Ramadhan *et al*. (2010)
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 (low temperature cooked meat)	• 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)
Spanish wild ducks	• To study the chemical and fatty acid composition of the liver and the meat from breasts and legs of Spanish wild ducks	Cobos *et al*. (2000)

Table 5: Reasons for lack of acceptance of the duck meat by the consumers

Reasons	Factors affecting	Reference
Higher price and lack of tradition for consumption	Higher production cost and feed	Bernacki *et al*. (2008)
Sharp cheesy odor with the fatty odor	Longer chain length of aldehydes. Aldehydes are important components that impart a fatty odor	Soncin *et al*. (2007)
Ducky like flavor	Free amino acids, peptides, inorganic salts and flavor nucleotides	Liu *et al*. (2007)
Ducky like odor	Volatile compounds such as aldehydes and hexanoic acid	Soncin *et al*. (2007)
Higher fat content	Diminution of moisture content in cooked product	Bhattacharyya *et al*. (2007)
Higher fat content	Diminution of moisture content in cooked product	Biswas *et al*. (2006)
Less juicy, tougher and less palatable	Age, genotype, sex and environmental (mostly nutrition) conditions	Biswas *et al*. (2006)
Higher fat content	Health conscious consumers prefer low-fat and high-protein products	Plavnik *et al*. (1982)

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. Because meat from duck is higher in fat and dark color than chicken, whereas the spent layer is tough and dry due to its high connective tissue content, it is less preferred by consumers than its fresh form. 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.

It is believed that there are potential applications for poultry meat in surimi processing. The unique nature of this poultry surimi lends itself to becoming the base for a range of novel products. Poultry surimi can be used as a major or minor ingredient in sausages, burger, nugget, kebabs, pate, sliced cooked meat, reformed meats and other products. However, further study on poultry surimi-like material, especially from non-chicken poultry meat such as duck, turkey and quail, is necessary in the future.

CONCLUSIONS

The application of surimi technology in the production of a surimi-like material from poultry meats could provide a new approach to increasing its value and utilization because there is a potential opportunity for low-value manufacturing poultry meat (duck, turkey, quail and spent hens) and oversupply of lower-value cuts with limited markets to be processed to a higher value poultry meat protein source. The question to be answered is, can poultry meat be a surimi replacer? Because poultry meat possesses good animal protein quality as well as lower fat and saturated fatty acid contents compared to those of red meat, there is a higher potential of poultry meat to be a surimi replacer. However, most studies of poultry surimi-like material have only focused on chicken; further studies related with non-chicken poultry surimi are necessary in the future.

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