

## Review Article

# Surimi-like material: challenges and prospects

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**Abstract:** The scarcity of Alaska pollock as surimi raw material has brought a new trend in surimi manufacture. New sources for surimi are obtained from other new species other than fish, and it is called surimi-like material. Research showed that surimi-like materials have functional properties that have made it suitable as functional meat. Many kinds of species have been studied as surimi-like material source such as beef, pork, sheep meat, and from poultry meat products. Poultry is one of potential source of surimi-like material. However, the study concerning the gel properties of surimi-like material made from non-chicken poultry meat such as duck, turkey, and quail is limited. Another challenge is in the use of various cryoprotectants other than the common cryoprotectants. The application of the surimi technology in the production of a surimi based product from other meats could provide a new approach towards increasing its value and utilization.

**Keywords:** Surimi, surimi-like material, cryoprotectant, poultry

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### Introduction

The objective of this review is to give a brief explanation about the new trend in surimi manufacture and why surimi-like materials are important. A slight view about research related to the development of surimi is also included in this review.

Surimi is stabilized myofibrillar protein obtained from mechanically deboned fish flesh that is washed with water and blended with cryoprotectant. In general, surimi is processed through mincing, washing, mixing with cryoprotectant, and freezing (Park, 2005). There are several types of fish that are commonly used as surimi raw material. They are Alaska pollock, Pacific whiting, arrowtooth flounder, blue whiting, mackerel, menhaden, bigeye snapper, threadfin bream, lizardfish, croaker, and tilapia. (Benjakul *et al.*, 2004; Guenneugues and Morrissey, 2005; Perez-Mateos and Lanier, 2006; Rawdkuen *et al.*, 2008; Campo-Deano and Tovar, 2009).

Surimi is served as a potential raw material for a variety of products such as imitation crab meat, kamaboko, flavored kamaboko, chikuwa, satsumi-age / tenpura, hanpen, and fish sausage. Surimi becomes increasingly popular due to its unique textural properties as well as high nutritional value (Park, 2005; Jin *et al.*, 2009). Therefore, it has

become the intermediate material for surimi based product (Zhou *et al.*, 2005). Surimi has long been an important food ingredient in Japan, and nowadays surimi based products are also preferred in many other countries and many studies have been carried out on the process of surimi (Trondsen, 1998; Park, 2005; Venugopal, 2006; Phatcharat *et al.*, 2006; Jin *et al.*, 2007; Catarci, 2007).

### *Factors affecting functional properties of surimi*

Surimi possesses 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.*, 2005). 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 of protein can be seen in Table 1. Many researchers have attempted to study surimi functional properties and factors that can impact to its functional properties. Factors affecting surimi functional properties may affect surimi manufacturing process, such as during

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**Table 1.** Functional properties requirement of surimi and factors affecting

No.	Functional properties	Mechanism	Factors affecting
1	Gelation (Park, 2005)	During heating of salted surimi pastes, the protein unfold, exposing the reactive surfaces of neighboring protein molecules, which then interact to form intermolecular bonds. When sufficient bonding occurs, a three dimensional network is formed, resulting in a gel	Extent of denaturation and premature aggregation of the myofibrillar proteins before manufacturing Species and habitat of raw material which determine the heat stability of the myofibrillar protein Activity of proteolytic enzymes, which will cleave proteins and disrupt the gel Activity of endogenous or added protein oxidant, as well as cross linking enzymes, which contribute to protein cross-linking Relative concentration of myofibrillar vs sarcoplasmic and / or stroma protein
2	Water holding capacity (Zayas, 1997)	Water bounded by protein through interactions between molecules of water and hydrophilic groups of the protein side chains occurs via hydrogen bonding	Protein concentration pH Ionic strength Temperature Presence of other components of food Lipids and salt Rate and length of heat treatment Condition of storage
3	Emulsification (Smith, 2001)	The protein film is comprised of solubilized and extracted myofibrillar proteins. During emulsification, the solubilized and extracted proteins must diffuse to the surface of the oil droplets and then adsorb onto the surface of the droplet	Temperature Sufficient energy input Undenatured/denatured protein Sufficient protein concentration Sufficient quantity of extractable protein Droplets surface area

washing treatments, cryoprotectants and phosphates addition and frozen storage.

One of the important criteria in the evaluation of surimi quality is gel formation. The multiple washing cycles in surimi processing is aimed at obtaining a high concentration of the salt soluble protein and also a bland colour, which can mix well with other ingredients to produce value added products (Babji *et al.*, 1995).

Conventionally, surimi is made through water washing process, but advanced washing process by using acid-alkaline is widely studied. Campo-Deano *et al.* (2009) reported that washing method with an acid solution ( $H_3PO_4$ ) preserved the functionality of the myofibrillar proteins better than washing method based on protein precipitation at the isoelectric point.

A study was conducted on the biochemical and

gel properties of tilapia surimi using conventional washing method and protein was isolated using alkaline-acid-aided processes. Higher protein yield and greater lipid and pigment reductions of tilapia muscle were achieved with the acid-alkaline-aided process than with the conventional washing process. However, conventional surimi showed higher gel strength (Rawdkuen *et al.*, 2009). While, according to Perez-Mateos and Lanier (2006), alkaline solubilization processing produced the highest gelling quality only in one washing step but, it gave poorer colour than conventional washed surimi from Atlantic menhaden.

Frozen storage is widely used in the surimi industries for processing and long term preservation. Nevertheless, the biochemical changes during frozen storage are associated with the reduction of the gelation properties of surimi and such reduction is

attributable to the denaturation of myofibrillar protein. Extended frozen storage of four fish species (threadfin bream, bigeye snapper, lizardfish, and croaker) at  $-18^{\circ}\text{C}$  caused the loss in gel forming ability, which was associated with protein denaturation (Benjakul *et al.*, 2004).

Cryoprotectant is a certain substance, when present at high concentration ( $>0.5\text{ M}$ ) stabilize the activity of enzymes in solution and during freeze-thawing (Park, 2005). Commercial cryoprotectant which is commonly used in surimi industry is the 1:1 mixture of sucrose and sorbitol (Zhou *et al.*, 2006). However, one disadvantage of these commercial cryoprotectant used is the high level of sucrose and sorbitol which impart a sweet taste that maybe undesirable especially to the western consumer in particular (Sultanbawa and Li-Chan, 1998).

Many studies have been done using other cryoprotectants with reduced or no sweetness and calorie content, such as: lactitol, litesse®, trehalose, palatinit, polydextrose®, and maltodextrin (Sultanbawa and Li-Chan, 1998; Zhou *et al.*, 2006; Carvajal *et al.*, 1999; Sych *et al.* 1990). Zhou *et al.* (2006) reported that trehalose and sodium lactate at levels of 8% (w/w) effectively prevented the protein denaturation of tilapia surimi during frozen storage  $-18^{\circ}\text{C}$  for 24 weeks. List of researches related to alternative cryoprotectant can be seen in Table 2.

#### *Surimi-like material as alternative functional meat*

According to Babji *et al.* (1995), the supply of surimi raw material is decreasing. Alaska pollock, the largest fishery biomass used for surimi, has decreased in harvest from over 6.5 million ton in late 1980's to less than 3 million ton since the year 2000 (Guenneugues and Morrissey, 2005). Hence, it is needed to look at other economically available resources of protein base raw materials to manufacture value added products from the high quality surimi gel. This trend can be seen in the FAO fishery report (Figure 1).

The scarcity of supply also resulted in the increase of Alaska pollock's price. Hence, the utilization of new species in the production of surimi has increased. Utilization other fish than Alaska pollock, for example, Pacific whiting for surimi production showed rapid growth in the 1990's. However, the Pacific whiting has a major quality problem where a heat-stable protease enzyme in the muscle tissue causes gel softening. This problem is also found in arrowtooth flounder (Guenneugues and Morrissey, 2005).

Tropical and pelagic fish are considered as alternative raw material for surimi production.

Tropical fish which are used in surimi production around Southeast Asia are mainly threadfin bream, bigeye snapper, croakers, and lizardfish. There are continuing questions, however, in the fisheries management and sustainability of the fisheries and industry in these areas. Pelagic fish that have been traditionally used in Japan for surimi production is atka mackerel. However, surimi made from this fish has a dark colour, relatively low gel strength, and a strong "fishy taste" (Guenneugues and Morrissey, 2005).

Overall, the surimi industry is not suffering from a lack of resources and it can be expected that a new number of new species will be utilized in surimi production during the coming years through new technology (Guenneugues and Morrissey, 2005). Hence, 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).

Other reason for the development of surimi-like material from species other than fish is the availability of low value meats and by-products for use in consumer foods (Kenny *et al.*, 1999). The characteristic of surimi like materials from beef, beef heart as meat by product, pork, sheep meat, giant squid, include from poultry meat product have been studied.

The study on surimi-like material from beef and pork revealed that gel forming ability and WHC of surimi-like material from pork was enhanced by the addition of NaCl at 1.5 or 3% (Park *et al.*, 1996). Surimi-like material made from sheep washed by using centrifugation resulted in a sharp reduction in the fat content and an increase in lightness, yellow colour, water content and pH of the mince. The washed mince produced excellent gels and had lower expressible fluid compared to that of the unwashed mince (Antonomonolaki *et al.*, 1999). Campo-Deano (2009) reported that surimi-like material made from giant squid washed by using an acid solution have better preservation of the functionality of myofibrillar protein, thus producing a better gel structure compared to surimi-like material made by using protein precipitation method.

Beef heart is a meat by product that has limited use in formulated muscle foods. Beef heart has been studied related to its chemical and functional properties in the making of surimi-like material. Parkington *et al.* (2000) concluded that modification of beef heart surimi functionality can be achieved through different washing processes. Parkington *et al.* (2000) found that the addition of propyl gallate and sodium tripolyphosphate inhibited lipid oxidation

**Table 2.** List of research related to alternative cryoprotectant in surimi and their main result

No.	Sample	Cryoprotectant	Main Results	Reference
1.	Cod	Lactitol, palatinit <sup>®</sup> , polydextrose <sup>®</sup> , sucrose, sorbitol	Palatinit <sup>®</sup> , lactitol, and polydextrose <sup>®</sup> stabilized surimi proteins equally well as did the sucrose/sorbitol mixture	Sych <i>et al.</i> , (1990)
2.	Ling cod	Lactitol, litesse <sup>®</sup> , sucrose, sorbitol	Cryoprotectant blend total concentrations of 4-12% were all effective in ensuring good gel formation during frozen storage at -18°C for 4 months	Sultanbawa and Chan (1998)
3.	Alaska Pollock	Maltodextrins, sucrose, sorbitol	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	Carvajal <i>et al.</i> (1999)
4.	Bigeye snapper	Phosphate compound	Microstructure study revealed that a gel with a fine network was formed with addition of PP. Therefore, the addition of PP in combination with CaCl <sub>2</sub> could increase the gel strength and WHC	Julavittayanukul, <i>et al.</i> (2005)
5.	Tilapia	Trehalose, sodium lactate, sucrose, sorbitol	Trehalose exhibited the greatest protective effect on protein denaturation, in concentration of 8 %, trehalose obtained surimi with the greatest breaking force and deformation during frozen storage at -18°C for 24 weeks. Sodium lactate showed a similar cryoprotective effect to sucrose/sorbitol blend	Zhou <i>et al.</i> (2006)

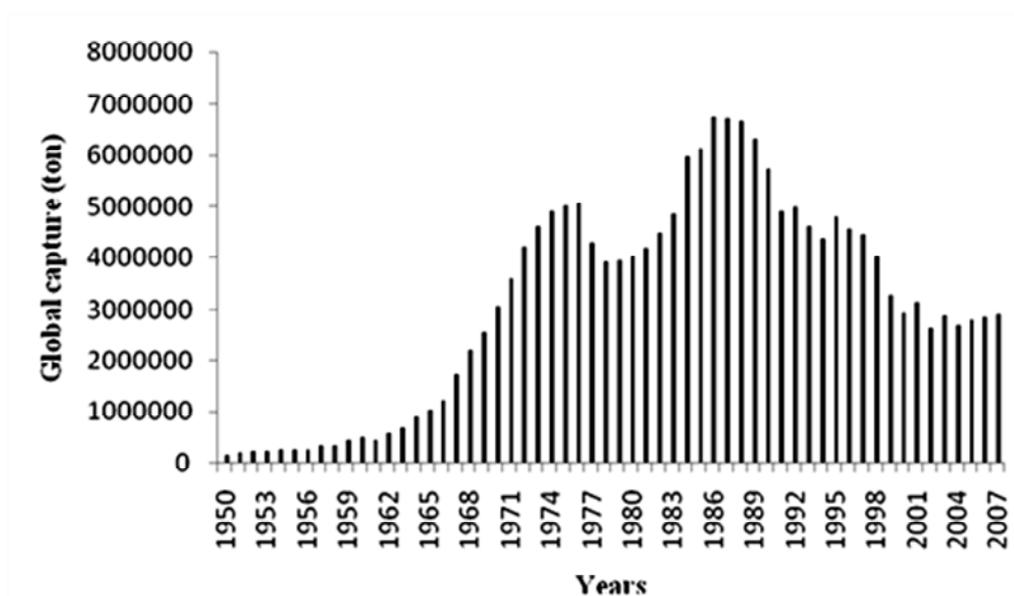


Figure 1. Global capture production for Alaska pollock (FAO, 2009a)

and increased gel elasticity.

Surimi-like material made from poultry (chicken) is widely studied (Yang and Froning, 1992; Babji and Gna, 1994; Babji *et al.*, 1995; Wang *et al.*, 1997; Nowsad *et al.*, 1999; Jin, *et.al.* 2009). The processing efficiency and physico-chemical properties of surimi type materials (beef, poultry (chicken), beef heart, tilapia, etc) study revealed that the highest yields belonged to chicken surimi as high as 70.5 % (Babji *et al.*, 1995). Surimi-like material made from poultry (chicken) also showed the maximum gel strength among other materials. From that study it can be seen that poultry has potential as low cost protein based raw material with high functionality property compared to other types of materials.

Studies on surimi-like material showed that surimi-like material can also be processed into functional meat. Table 3 shows research related to surimi-like material.

#### *Challenges and prospects of surimi-like material as alternative functional meat*

The functional properties of surimi-like material made it suitable as a functional meat. However, there are still challenges and also prospects on its development. One of the challenges for the improvement of this alternative functional meat is the use of various cryoprotectants other than the common cryoprotectants like sucrose and sorbitol. Meanwhile, the application of the surimi technology in the production of a surimi based product from other meats such as poultry could provide a new approach towards increasing its value and utilization. Meat consumers and processors can also benefit from the development of efficient and economical technology for processing undervalued meat into value added meat products that are palatable and reasonable in cost (Jin *et al.*, 2008).

To address the scarcity of surimi raw materials, it is important to find other new sources. Poultry has prospect as a new source of surimi-like material. Poultry has many advantages. It is easy to rear and has a small size so that it can be processed in small scale. It is reported that worldwide poultry meat production achieved 87,584,830 ton in 2007 (FAO, 2009b).

Spent hen/duck that have outlived their productive lives are potential sources of poultry meat, at the end of their egg laying cycle (Nowsad *et al.*, 1999). Hence, the poultry industry must find economical means in order to find a solution to the problem of mortality and litter disposal of spent hens/duck. Spent hens have low market value, because spent hen meat has higher collagen content, and is thus not well accepted by the consumers (Lee, 2003).

Babji and Gna (1994) reported that the grinding and washing process of broiler and spent hen meat reduced sarcoplasmic protein, but increased salt soluble protein, pH and WHC. Washing produced a desirable gel in broiler chicken and spent hen surimi-like material compared to the original raw meat (Babji and Gna, 1994). Babji *et al.* (1995) concluded that it is practical to process surimi-like materials such as spent hen, old beef animal, Mechanically Deboned Chicken Meat (MDCM) and tilapia into surimi-like material into further products.

Nowsad *et al.* (1999) found that 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 of surimi. Li (2006) concluded that myofibrillar protein from spent hen meat may be used to improve the functional properties of whole-muscle meat products.

However, the study of poultry surimi like material only focused on chicken. 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.

Duck is one of non-chicken poultry meat which has a prospect to be used as a new source of surimi-like material. Duck production is important for many Asian countries (Tai and Tai, 2001). Main producer countries of duck meat are shown in Table 5.

Malaysia for example, is the third highest country that produced duck meat annually 111,000 ton in 2007 (FAO, 2009b). Duck production is rapid in this country. It reached approximately 154% of population growth since 1996 until 2004 (Department of Veterinary Services Malaysia, 2009).

Duck has many benefits compared to chicken. It has a lower price and is also less susceptible to diseases. Saito *et al.* (2009) found that pathogenicity of highly pathogenic avian influenza viruses of H5N1 subtype in different poultry species is less in duck. The viruses caused death in chicken and quails within 2-4 days of inoculation, while mortality against domestic and cross-bred ducks ranged from 50 to 75%. The study on duck surimi-like material is necessary. However, the major obstacle is the high fat content and dark meat of duck.

#### **Conclusion**

The development of surimi-like material as functional meat has its own challenges and prospects. The application of the surimi technology in the production of a surimi based product from other meats

**Table 3.** Research related to surimi-like material and their main results

No	Raw material	Main Results	Reference
1.	Beef, pork	Gel forming ability of beef or pork surimi-like material were enhanced by addition of NaCl at 1.5 or 3% NaCl	Park <i>et al.</i> (1996)
2.	Beef heart	Propyl gallate inhibited lipid oxidation but was ineffective against protein changes After 12 weeks, cryoprotectants promoted lipid and protein oxidation in the absence of propyl gallate	Wang <i>et al.</i> (1997)
3.	Beef heart	Addition of propyl gallate and sodium tripolyphosphate inhibited lipid oxidation but did not prevent protein oxidation. Gel elasticity increased and emulsifying activity decreased for all surimi samples during storage, coinciding with myosin degradation	Parkington <i>et al.</i> (2000)
4.	Poultry (Chicken)	Gel strength and breaking strength were higher in spent hen compared to broiler surimi, while, gel elasticity, springiness, and water retention properties were almost identical in two surimi Cryoprotectant increased the gel strength of fresh surimi from both hen and broiler.	Nowasad <i>et al.</i> (1999)
5.	Poultry (Chicken)	Washing 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 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)
6.	Poultry (Chicken)	Grinding and three washings reduced the sarcoplasmic proteins Grinding and three washings increased extractable salt soluble proteins, pH, and WHC and also the L* and a* value but the b* value decreased Washing produced a desirable gel in both broiler chicken and spent hen compared to the original raw meat	Babji and Gna (1994)
7.	Poultry (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 It is practical to process surimi-like materials from low cost raw materials	Babji <i>et al.</i> (1995)
8.	Pork and Poultry (Chicken)	Yield and collagen content was significantly higher in pork leg surimi by washing two times than others Myoglobin content was higher in pork leg surimi	Jin <i>et al.</i> (2009)
9.	Giant squid	Washing with an acid solution preserves the functionality of the myofibrillar proteins better, thus making for a better gel structure than washing with protein precipitation at the isoelectric point In protein precipitation washing surimi, trehalose favoured less initial protein aggregation and hence a thermorheologically stable structure, with a better gelation profile than sorbitol+sucrose or sorbitol+trehalose	Campo-Deano <i>et al.</i> (2009)
10.	Sheep	The washing method resulted in a sharp reduction of fat content and expressible water, but an increase in moisture content, lightness, yellowness and pH of the mince The washed mince was produced excellent gel as measured by the folding test, elasticity modulus, and the percentage of recovery	Antonomanolaki <i>et al.</i> (1999)
11.	Mutton	Washing increased moisture and decreased fat and protein content in surimi-like material 2. Percentage of 14:0, 16:0, 18:0. And 18:1 fatty acids tended to decrease and percentage of polyunsaturated fatty acids tended to increase with washing.	McCormick <i>et al.</i> (1996)

**Table 4.** Worldwide poultry meat production in 2007 (FAO, 2009b)

Commodity	Meat Production (ton)
Chicken	75,826,354
Turkey	5,868,167
Duck	3,583,809

could provide a new approach towards increasing its value and utilization which are palatable and reasonable in cost. One of the potential new sources of surimi-like material is poultry. However, the study of poultry surimi like material only focused on chicken. There has been limited research concerning the gel properties of surimi-like material made from non-chicken poultry meat which have vast meat production. Another challenge is the uses of various cryoprotectants other than common cryoprotectant like sucrose and sorbitol, the high fat and dark meat content in duck meat presents another challenge in the production of surimi like material from duck.

**Table 5.** Main producer countries of duck meat in year 2007 (FAO, 2009b)

Country	Duck meat production in 2007 (ton)
China	2,328,796
France	234,360
Malaysia	111,000
Thailand	85,000
Vietnam	84,000

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### References

- Antonomanolaki, R.E., Varelziz, K. P., Georgakis, S.A. and Kaldrymidou, E. 1999. Thermal gelation properties of surimi like material made from sheep meat. *Journal of Meat Science* 52: 429-435.
- Babji, A.S., Mukhlis, I., Gna, S.K., Seri Chempaka, M.Y., Norhaliza, M. and Eraou, B. 1995. Processing efficiency and physico-chemical properties of surimi type materials. *Malaysian Journal of Animal Science* 1: 52-58.

Babji, A.S., and Gna, S.K. 1994. Changes in colour, pH, WHC, protein extraction and gel strength during processing of chicken surimi (ayami). *ASEAN Food Journal* 9: 54-59.

Benjakul, S., Visessanguan, W., Thongkaew C. and Tanaka, M. 2004. Effects of frozen storage on chemical and gel forming properties of fish commonly used for surimi production in Thailand. *Journal of Food Hydrocolloids* 37: 177-185.

Benjakul, S., Visessanguan, W. and Tueksuban, J. 2003. Heat-activated proteolysis in lizardfish (*Saurida tumbil*) muscle. *Food Research International* 80: 535-544.

Campo-Deano, L. and Tovar, C. 2009. The effect of egg albumen on the viscoelasticity of crab sticks made from Alaska pollock and Pacific whiting surimi. *Journal of Food Hydrocolloids* 23: 1641-1646.

Campo-Deano, L.C., Tovar, C.A., Pombo, M.J., Solas, M.T. and Borderias, A.J. 2009. Rheological study of giant squid surimi (*Dosicus gigas*) made by two methods with different cryoprotectants added. *Journal of Food Engineering* 94: 26-33.

Guenneugues, P. and Morrissey, M.T. 2005. Surimi resources. In Park, J.W. (Ed). *Surimi and Surimi Seafood* 2nd edn, p. 375-433. Boca Raton, FL: CRC Press.

Catarci, C 2007. Surimi market report - December 2007. Downloaded from <http://www.globefish.org/dynamisk.php?id=4356> on 18/10/2009

Internet: Departement of Veterinary Services Malaysia 2009. Livestock statistic. Downloaded from <http://www.dvs.gov.my/population> on 01/08/2009

Internet: FAO 2009a. FAO species identification and data programme: *Theragra chalcogramma* downloaded from <http://www.fao.org/fishery/species/3017/en> on 18/07/2009.

Internet: FAO 2009b. Livestock primary. Downloaded from <http://faostat.fao.org/site/569/default.aspx#ancor> on 22/07/2009.

Jin, S. K., Kim, I.S., Choi, Y.J., Kim, B.G. and Hur, S.J. 2009. The development of imitation crab stick containing chicken breast surimi. *Journal of Food Science and Technology* 42: 150-156.

Jin, S.K., Kim, I.S., Kim, S. J., Jeong, K. J., Choi, Y.J. and Hur, S. J. 2007. Effects of muscle type and washing times on physicochemical characteristic and qualities of surimi. *Journal of Food Engineering* 81: 618-623.

- Julavittayanukul, O., Benjakul, S. and Visessanguan, W. 2005. Effects of phosphate compounds on gel-forming ability of surimi from bigeye snapper (*Priacanthus tayenus*). *Journal of Food Hydrocolloids* 20: 1153-1163.
- Kenny, T, Desmond, E. and Ward, P. 1999. Up-grading of low-value meats and by-products for use in consumer foods, p. 1-26. Dublin, Ireland: The National Food Centre.
- Li, C.-T and Wick, M. 2001. Improvement of the physicochemical properties of pale soft and exudative (PSE) pork meat products with an extract from mechanically deboned turkey meat (MDTM). *Journal of Meat Science* 58: 189-195.
- Li, C.T. 2006. Myofibrillar protein extracts from spent hen meat to improve whole muscle processed meats. *Journal of Meat Science* 72: 581-583.
- Matsumoto, J.J and Noguchi, S.F.1992. Cryostabilization of protein in surimi. In Tyre, C.L. and Chong, M.L. (Eds). *Surimi Technology*, p. 357-383. New York, USA: Marcel Dekker, Inc.
- McCormick, R.J., Bugren, S., Field, R.A., Rule, D.C. and Busboom, J.R. 1993. Surimi-like products from mutton. *Journal of Food Science* 58: 497-500.
- Nowsand, A.A.K.M., Kanoh, S. and Niwa, E. 2000. Thermal gelation characteristics of breast and thigh muscles of spent hen and broiler and their surimi. *Journal of Meat Science* 54: 169-175.
- Park, J.W. 2005. Surimi seafood: products, market, and manufacturing. In Park, J.W. (Ed). *Surimi and Surimi Seafood*, p. 375-433. Boca Raton: CRC Press.
- Park, S., Brewer, M.S., Novakofski, J., Bechtel, P.J. and McKeith, F., K. 1996. Salt, cryoprotectants and preheating temperature effects on surimi-like material from beef or pork. *Journal of Food Science* 61: 422.
- Parkington, J.K., Xiong, Y.L., Blanchard, S.P., Xiong, S., Wang, B., Srinivasan, S. and Froning, G. W. 2000. Chemical and functional properties of oxidatively modified beef heart surimi stored at 20C. *Journal of Food Science* 65: 428-433.
- Perez-Mateos, M. and Lanier, T.C. 2006. Comparison of Atlantic menhaden gels from surimi processed by acid or alkaline solubilization. *Journal of Food Chemistry* 101: 1223-1229.
- Phatcharat, S., Benjakul, S., Visessanguan, W. 2006. Effects of washing with oxidising agents on the gel-forming ability and physicochemical properties of surimi produced from bigeye snapper (*Priacanthus tayenus*). *Journal of Food Chemistry* 98: 431-439.
- Rawdkuen, S., Sai-Ut, S., Khamsorn, S., Chaijan, M. and Benjakul, S. 2009. Biochemical and gelling properties of tilapia surimi and protein recovered using an acid-alkaline process. *Journal of Food Chemistry* 112: 112-119.
- Saito, T., Watanabe, C., Takemae, N., Chaisingh, A., Uchida, Y., Buranathai, C., Suzuki, H., Okamoto, M., Imada, T., Panchariyanon, S., Traiwanatam, N. and Yamaguchi, S. 2009. Pathogenicity of highly pathogenic avian influenza viruses of H5N1 subtype isolated in Thailand for different poultry species. *Journal of Veterinary Microbiology* 133: 65-74.
- Smith, D. M. 2001. Functional properties of muscle proteins in processed poultry products. In Sams, A.R. (Ed). *Book Reviews Poultry Meat Processing*, p. 181-194. New York, USA: CRC Press.
- Sultanbawa, Y., and Li-Chan, E. C. Y. 1998. Cryoprotective effects of sugar and polyol blends in ling cod surimi during frozen storage. *Food Research International* 31: 87-98.
- Sultanbawa, Y., and Li-Chan, E., C., Y. 2001. Structural changes in natural actomyosin and surimi from ling cod during frozen storage in the absence or presence of cryoprotectants. *Journal of Agricultural and Food Chemistry* 49: 4716-4725.
- Sych, L., Lacroix, C., Adambounou, L.T., and Castaigne, F. 1990. Cryoprotective effects of lactitol, palatinit, polydextrose®, on cod surimi proteins during frozen storage. *Journal of Food Science* 55: 356-360.
- Tai, C and Tai, J.J.L. 2001. Future prospect of duck production in Asia. *Journal of Poultry Science* 38: 99-112.
- Trondsen, T. 1998. Blue whiting surimi: new perspectives on the market value. *Journal of Fisheries Research* 34: 1-15.
- Venugopal, V. 2006. *Seafood processing: Adding value through quick freezing, retortable packaging, and cook-chilling*. Boca Raton: CRC Press.
- Wang, B., Xiong, Y.L., and Srinivassan, S. 1997. Chemical stability of antioxidant-washed beef heart surimi during frozen storage. *Journal of Food Science* 62: 939-945.
- Xiong, Y.L. 1997. Structure-function relationships of muscle proteins. In Damodaran, S. and Paraf, A. (Eds). *Food Proteins and Their Applications*, p. 341-392. New York, USA : Marcel Dekker.
- Yang, T.S., and Froning, G.W. 1992. Selected washing processes affect thermal gelation properties and microstructure of mechanically deboned chicken

meat. *Journal of Food Science* 57: 325-329.

Zayas, J.F. 1997. *Functionality of proteins in food*. Berlin, German: Springer-verlag.

Zhou, A., Benjakul, S., Pan, K., Gong, J. and Liu, X. 2006. Cryoprotective effects of trehalose and sodium lactate of tilapia (*Sarotherodon nilotica*) surimi during frozen storage. *Journal of Food Chemistry* 96:96-103.