3. UTILIZATION OF FISHBONE FLOUR IN FOOD PRODUCTS

Fishbone flour is a by-product of fish processing and represents a cheap source of high-quality nutrients for the human diet because of high levels of amino acids and polyunsaturated fatty acids. Fish matrix also has a very low content of carbohydrate and a very low glycemic index so it's suitable as a wheat flour substitute (Oliveira, 2015). Maria Lucia (2016) reported that the replacement of wheat flour by tilapia flour increased the nutritional quality of noodles because it give greater protein and lipid contents due to the high-quality of essential fatty acids and amino acids content in it. Based on Maria Lucia (2016) and Sarah Nur Halimah (2016), the usage of Tilapia and Catfish fishbone flour as wheat flour subtitute can give an appearance of yellowish color to noodles. Elenice (2016), found that the inclusion of up to 30% of tilapia protein concentrate in fresh wet noodle can linearly increase the crude protein and total lipid contents, decrease the caloric value, increase the calcium, phosphorus, magnesium, sodium, and zinc concentration.

There are several studies about the utilization of snakehead fishbone as calcium fortificant on crackers (Kim & Mendis, 2006), dried noodle products (Mulia, 2004), and Cookies (Tawali, 2018). Nile tilapia fishbone can be used to produce gelatin and it has better functional properties than commercial gelatin (bovine gelatin) in panna cotta (Tinrat, 2017). Sirichokworrakit (2014) reported that fishbone of nile tilapia can give good acceptable cooking quality, textural, color, and sensory characteristics in noodles. The replacement of wheat flour by tilapia flour increased the nutritional quality of dried pasta with greater protein and lipid contents containing high quality essential fatty acids and amino acid profiles. This replacement is a suitable strategy to improve the nutritional aspects of dried pasta without negatively affecting the storage quality of the product during at least 21 days at 25^0C (Maria Lucia, 2016). Fortification of noodles with catfish bone powder resulted in a yellowish color appearance, specific flavorful noodles, and they taste just as noodles from flour and springy (Sarah, 2016).

There are at least 29 variants of collagens based on sequence homology and molecular structure (Wang,2008). The four main types of collagens are type I, II, III, and IV. Based on their structure and supramolecular organization, collagens are classified into fibril-forming collagen, fibril-associated collagen, network-forming collagen, anchoring fibrils, transmembrane collagen, basement collagen, etc (Gelse *et al*, 2003). Type I collagen is a fibril forming collagen which primarily found in connective tissue such as skin, bone, and tendons (Schrieber & Gareis, 2007). Kasankala *et al* (2007) said that collagen can be found in the skin and bone of animals and fish producing a higher quality of gelatin when it undergoes thermal denaturating. The first change to occur by heating collagen is the shortening of the length of collagen. Boiling collagen at normal temperature and pressure does not damage collagen content. At higher temperatures, there is the conversion of collagen to gelatine and it will change at 527^0F (300^0C).

Collagen denaturations cause separation of rods and total or partial separation of the chain due to the destruction of hydrogen bonds causing the loss of triple helix conformation and the following denaturation polymer will exist in the coiled form (Karim & Bhat,2009). Above 527^0F collagen, proteins will undergo a degradation that cannot be reversed. Gelatin is a partially hydrolyzed form of collagen and it finds application in the food and packaging industry for microencapsulation and light-sensitive coating (Senaratne, 2006). The molecular weight of gelatin ranges from 97 kDa until >250 kDa which produces in acid or alkaline condition (Mariod & Fadul,2013). Gelatin was used as food additives and functional food in food industries. As food additive, gelatin used as an emulsifier, stabilizer, gelling forming, thickener, adhesive agent, and biofilm. As functional food, gelatin has been developed in the form of peptide for antidiabetic, antimicrobial, antioxidant, and antihypertensive (Gomez-Guillen *et al*, 2011).

Freshwater fishes can be classified into 3 categories based on the temperature of its environment which are warm-water fish species, cold-water species, and a mixture of both. Cold-water fishes are fishes that live in waters in which the maximum mean monthly temperature does not exceed 20^0C and when the habitat is favorable, it can support a year-round population of cold water stenothermal aquatic life. Warm-water fishes are fishes that live in a warmer environment. The mixture of cold and warm water fishes are fishes that can live in both habitat, commonly there is a transition from a cold to a warm-water fishery along its stream (Flanagan,1999). Fishbone gelatin from warm-water fishes has a superior amino acid than cold-water fishes. This amino acid gives effect to the stability and gel strength of fishbone gelatin (Zhang, 2011). Fishbone gelatin from warm-water fishes has better thermostability and rheology than cold-water fishes (Gomez-Guillen, 2009). There are positive correlations between the composition of amino acid hydroxyproline (Hyp) and gel strength (Wang, 2009). If the content of amino acid hydroxyproline in fishbone flour is high, so it will improve the rheological such as viscoelasticity and gel strength in the product. Also, it will improve the stability of fish gelatine. Glycine in fishbone flour is important to develop gel strength in food products (Sanaei, 2013). In this study, we use *Channa striata*, *Clarias batrachus*, and *Tilapia nilotica* which are warm-water fishes.

Collagen could inhibit the denaturation processes of myofibril proteins and its composition influences the water holding capacity (WHC) of myofibril protein-based products also it gives an effect to the state of water contained therein. Myofibril protein-based product with added collagen gives a higher value of gel strength. Protein denaturation of myofibril protein-based products will reduce WHC that resulted in reducing gel strength and more lost in the lipid chain (Darmanto,1999). Water Holding Capacity is an ability of myofibril protein to bind molecules of water and shows the quality of protein. Higher WHC resulted in a higher quality of protein because WHC is protein gel's ability to retain water against a gravitational force. The addition of fish collagen in food has shown an impact especially in altering the rate of protein denaturation by retaining Ca-ATPase activity, Water Holding Capacity, and gel strength. The addition of collagen resulted in higher relative Ca-ATPase activity, higher WHC, and gel strength in food products (Darmanto, 2014).