

CHAPTER 2

LITERATURE REVIEWS

Soybean is the source of inexpensive and high quality protein. Soybean has been a staple of the human food in Asia, especially soymilk and tofu. In recent years, interest in soy foods has increased due to consumer concern about health. Soy foods provide protein of equal quality to other proteins and without saturated fats and cholesterol. Food and Drug Administration (FDA) has approved soy protein claims to lower serum cholesterol level as a lower risk in heart diseases and allowed food manufacturers to place a health claim on the package labels of food products containing more than 6.25 g of soy protein per serving. FDA recommends that consumers incorporate four serving of at least 6.25 g of soy protein into the diet for a total of at least 25 g of soy protein per day in order to reduce the risk of heart disease (Stein, 2000).

Tofu, a traditional soybean food in Asia, has been an important source of protein. It is a white or pale yellow soybean curd precipitated from hot soymilk with a coagulant such as CaSO_4 , MgSO_4 , CaCl_2 , MgCl_2 and Glucono- δ -lactone (GDL). It is inexpensive, nutritious, cholesterol-free, lactose-free, lowers in saturated fat and calories. In recent years, tofu has become increasingly popular throughout the world, as the number of consumers who are looking for health foods is increasing.

The process of making tofu involves a complex interaction of many factors, including chemical composition and physical attributes of the soybean and processing techniques and conditions. Many methods are available for making tofu. There are many factors affecting tofu preparation to balance the maximum both tofu yield and quality. In general, factors affecting soymilk preparation include soybean varieties whether soybeans are ground hot or cold, whether soy slurry is heated before or after filtration, the water to bean ratio and extent of heat applied to soymilk. Factors affecting coagulation include the temperature at which a coagulant is added, the type and concentration of coagulants, the mode of adding coagulants, the duration of coagulation and molding step, the pressure and time applied to press curds.

2.1 Factors involved tofu making

2.1.1 Soybean varieties

There are great variations among soybean varieties, in terms of physical appearance and chemical composition, protein and oil content, size, amount of water absorbed at complete hydration, protein concentration of soymilk, fresh tofu yield, tofu protein content and tofu hardness (Kim and Wicker, 2005). Traditionally, soymilk and tofu manufacturers prefer large-seed soybeans with clear hilum and high protein content. Tofu beans produced tofu with whiter color and better overall quality, compared to regular field beans known as oil beans (Ang et al., 1999). The most important attributes of soymilk and tofu are flavor, texture and yield. The chemical composition of soybeans should be more important than their physical appearance (Liu, 1997). Soybean varieties and growing locations affect the chemical and physical properties of soybean, soymilk and tofu. Protein contents of soybean are the most important factor determining the qualities of soymilk and tofu. Analysis on soybean protein can be used to predict the protein content of tofu and yield (Poysa and Woodrow, 2002; Min et al., 2005b; Panyathitipong and Puechkamut, 2008).

The protein compositions that are 7S and 11S effected on the tofu quality which varies with soybean variety and environment. It should be informative to determine the effect of their ratios (Prabhakaran et al., 2006; Tay et al., 2006) and their individual sub-unit content, on soymilk and tofu yield and quality prepared using the above techniques which would emphasize differences in protein quality, as the protein quantity is being kept constant (Poysa and Woodrow, 2002). The 11S content and 11S/7S protein ratio have been reported to correlate positively with tofu gel firmness on the basis of purified soy protein system (Murphy et al., 1997; Mujoo et al., 2003). The 11S gels made in the tofu coagulants were much harder than 7S gels and 11S mainly determined the hardness of tofu gels and 11S showed greater breaking force than 7S gels (Tay et al., 2006)

The effects of soybean varieties and growing locations on the volatile compounds are significant. It was found the total volatile compound content was related to concentration of soymilk protein. The volatile contents increased as the protein content of soymilk increased (Min et al., 2005a). Moreover, the different intensity in the colors of soybeans varieties affect on the color of soymilk caused by seed coat hilum. Khatib et al. (2002) reported that the different hilum colors of soybean seeds were due to the distribution of pigments in the seed coat, which could migrate to soymilk components upon grinding but did not affect the color properties of tofu.

2.1.2 Concentration of soymilk

The concentration of soymilk or total solids in soymilk is closely related to the water-to-bean ratio (Cai and Chang, 1997; Lakshmanan et al., 2006). It can be measured easily with a refractometer and expressed as °Brix. The ratio is the total weight of water added to the dried soybeans during soaking, grinding and cooking, divided by the original weight of the dry soybeans. The total water includes the water used for rewashing okara if applicable but excludes drained water and that used for washing beans. The amount of water needed to make soymilk is also important because it affects soymilk solid content and tofu texture. In general, higher solid content in soymilk correlates with a harder texture, yield of tofu and protein content of tofu (Beddows and Wong, 1987; Ohara et al., 1992; Cai and Chang, 1997; Shih et al., 1997; Poysa and Woodrow, 2002; Kong and Chang, 2009). High concentration of soymilk increased the tofu's apparent Young's modulus and reduced the syneresis rate (Liu et al., 2004) and increased the density of the network (Cheng et al., 2005). Soymilk solid content decreased when the water-to-bean ratio increased but no significant effect on protein recovery in dry tofu (Cai and Chang, 1997).

The viscosity of soymilk increased exponentially with increasing soymilk concentration (Cheng et al., 2005). In general, tofu manufacturers use soymilk with a solid content ranging between 5% and 12% (Ang et al., 1999).

2.1.3 Heat process of soymilk

The heating of soymilk is a prerequisite for formation of tofu gel by unfolding soybean protein molecules. The SH-groups and hydrophobic amino acid side chains are exposed. The negative charges on the protein molecules are decreased by protonation of coagulant when coagulant is added. Protein molecules come close together owing to the decrease of electrostatic repulsion leading to formation of tofu gel with a three dimensional network structure. The optimum heating time-temperature combination corresponds approximately to the maximum range of SH-groups (Liu, 1997). Heat treatment on soybean or soymilk used in tofu preparation can be one of the methods to control the texture of tofu (Yoon and Kim, 2007). It was reported that the texture and yield of tofu were affected by thermal treatments. Increasing coagulation temperature increased the tofu hardness but decreased the tofu yield (Sun and Breene, 1991; Hou et al., 1997). The hardness of tofu increased with heat treatment time. The increase in the hardness of tofu by heat treatment was explained that gel hardness increased with the amount of

disulfide bonding. Thus, increase in concentrations of 7S globulin and sulfur amino acids can cause a stronger gel to form. Therefore, it is hypothesized that the increased formation of disulfide bonding caused by the synthesis of basic 7S by heat shock produced firmer tofu than the control (Yoon and Kim, 2007)

Soymilk heated at different conditions was different in texture. In one step heating, induced the decrease in tofu apparent breaking strength and Young's modulus. In two step heating, increased the tofu's apparent Young's modulus, breaking strength and the structure of the network of the tofu was denser, finer and more homogeneous (Liu et al., 2004; Wang et al., 2007).

The longer heat treatment may have caused more Maillard browning and hence the formation of brown color causing and increasing in the yellowness of tofu (Yoon and Kim, 2007). Regardless of whether soymilk or soy slurry is heated; it is recommended that 10 min at near 100°C is optimum for heat treatment (Ang et al., 1999).

2.1.4 Type of coagulants

Coagulation is the most important step in tofu making process. At least four variables are involved in this step: the type of coagulants, the concentration of coagulants, the temperature of soymilk to which a coagulant is added, and the mode of adding and mixing the coagulant (Liu, 1997). Calcium sulfate, calcium chloride, magnesium sulfate, magnesium chloride and glucono- δ -lactone (GDL) are different type of coagulants used for industrial scale for the preparation of tofu. The tofu was formed due to the cross-linking of protein molecules in soymilk with the divalent cations such as Ca^{2+} or Mg^{2+} form bridges with the negatively charged protein by electrostatic interaction (Prabhakaran et al., 2006). The electrostatic interaction will cause the cations to form bridges with the proteins, which result in the formation of aggregates (Tay et al., 2006). The mechanism is shown in Figure 2.1. After the coagulation process, whey is removed for the preparation firm and hard tofu. Different coagulants used in soy gels result in products with varying flavor properties and textural characteristics. The texture of tofu should be smooth, firm and coherent (Liu, 1997).

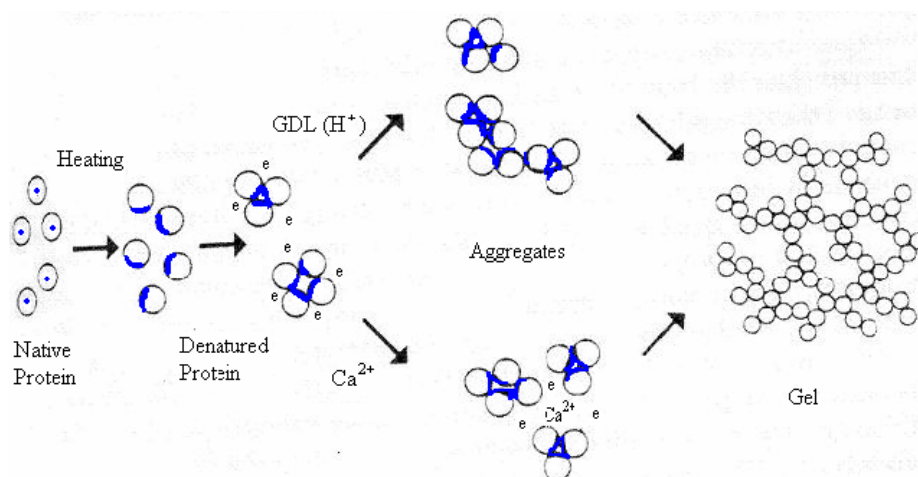


Figure 2.1 The gelation mechanism of soy protein with glucono delta lactone (GDL) or Ca²⁺

Source: Liu (1997)

Sulfate type such as MgSO₄ and CaSO₄ is the most widely used tofu coagulant. It is also the oldest one used in China (Ang et al., 1999). This coagulant is well suited to modern mass production methods for although they disperse slowly in water to form colloidal solutions which have a slow coagulation reaction time. It gives 15 to 20% higher bulk yields than nigari (chloride type). The tofu flavor varies from mild to bland, slightly inferior to that of nigari tofu. Sulfate type salt is sold in the form of a white powder, always stored in dry form and used in the amount of 2.2% by weight of dry soybean for making regular or firm tofu and 1.0% for making silken tofu (Shurtleff and Aoyagi, 2000). Calcium sulfate was also found to be a better coagulant than calcium chloride in terms of yield of tofu (Prabhakaran et al., 2006) due to chloride ion caused the decrease of electrostatic interaction more than sulfate ion which lead to the increase of syneresis and loss of whey from the curd (Tay et al., 2006)

Nigari or chloride type such as MgCl₂ and CaCl₂ is a by-product during production of table salt from seawater. It is a mixture of mineral compounds naturally found in and the sedimented from seawater, from which table salt has been mostly removed. It consists primarily of magnesium chloride plus all of the other salts and trace mineral in seawater. This coagulant has one great overriding virtue; it makes the most delicious tofu, prized for its wonderful subtle sweet flavor and aroma. Most tofu shops in Japan, used a nigari-type coagulant to make tofu. This coagulant is sold in powder, granular or flake forms and are used about 3.0 % by weight (Cai and Chang, 1997).

GDL (glucono- δ -lactone) is a fine, white, odorless, crystalline powder with a sour taste. It is an oxidation product of glucose. Industrially made from cornstarch and followed by a fermentation process. When it is dissolved in water, it is slowly hydrolyzed to gluconic. Lactone is different from nigari and gypsum types of coagulants because the coagulation by lactone results from the action of an acid rather than a salt. The great advantage of lactone as a tofu coagulant is that, by controlling temperatures, it allows the completion of mixing and packaging before coagulation. Thus, it is particularly suitable for automation and aseptic packaging. Since each type of coagulant has advantages and disadvantages, in commercial processes, a mixture of coagulants, such as that of GDL and calcium sulfate or magnesium chloride, is sometimes used (Ang et al., 1999).

Coagulants will produce tofu of different flavor and texture due to the coagulating power. Tay et al., (2006) reported that the coagulation powers of various salts were in order of $\text{CaCl}_2 > \text{MgCl}_2 > \text{CaSO}_4 > \text{MgSO}_4$. Coagulants with strong coagulation power were able to form uniform curds of firmer texture compared with those of weak coagulation power.

2.1.5 Concentration of coagulants

One of the most difficult and most important parts of tofu making is to determine exactly how much coagulant to add per given weight of dry soybean or volume of soymilk, because the amount of a coagulant is a major factor affecting tofu quality and yield (Sun and Breene, 1991; Liu, 1997). When a proper amount of coagulant is used, the whey becomes transparent with amber or pale yellow color and a sweet taste. However, if too much coagulant is added, the whey has a slightly bitter taste, its color turns more yellowish, and curds have a coarse and hard texture. In contrast, if too little coagulant is used, whey is cloudy, and there may be some uncoagulated soymilk remained. Within a certain concentration range, as the coagulant concentration increases, the tofu bulk yield and protein recovery decrease while the tofu hardness and elasticity increase (Ang et al., 1999). The yield of tofu decreased with increasing calcium ion concentration could be due to the increasing syneresis and loss of whey from the curd as more bonding occurred thus making the protein matrix more dense and compacted. At the lower concentration, bridging of protein molecules by calcium ion is not sufficient to form a firm gel. At higher concentrations, increased bridging and the resulting compaction of protein matrix cause increased syneresis and loss of water, whey protein and other solubles (Sun and Breene, 1991).

The network of tofu obtained with lower CaSO_4 concentration (0.2%) revealed a coarse and discontinuous structure with many fragments and large pores. On increasing of the CaSO_4 concentration, there was a trend toward decreasing pore size and increasing regularity and uniformity. The microstructure of tofu showed the most continuous and uniform with smaller holes than those prepared with 0.2% CaSO_4 . When increasing CaSO_4 to 0.5% the network of tofu became too porous and too compact and not as uniform and smooth (Kao et al., 2003).

Using optimal concentration of coagulant in soymilk is the most critical step among many steps of unit operations during tofu manufacturing for achieving high quality tofu. The optimal coagulant concentration varies not only with processing condition but also with soybean materials which are affected by variety and storage conditions (Poysa and Woodrow, 2002; Mujoo et al. 2003).

The optimal concentrations of coagulant for preparing tofu decreased with increasing either A_w or storage time due to the decrease in soymilk pH and the increase in organic acid content (Liu and Chang, 2008). This speculation was in agreement with the theory of the coagulation of soymilk in acidic compounds that could coagulate soy proteins to reduce the negative charges on soy protein molecules by the protonation of the $-\text{COO}^-$ on acidic amino acid residues. The pH reduction enhanced the extent of Ca^{2+} binding to soy proteins (Kroll, 1984). It was observe that when the respective optimal amount of coagulant was applied, pH of coagulum decreased with increasing A_w or storage time (Liu and Chang, 2008).

When soymilk was prepared by fixing the water-to-bean ratio despite the different storage conditions, the soymilk protein content or total solids content decreased with the adversity of soybean storage condition (Hou and Chang, 2003). The optimal coagulant concentration decreased with decreasing soymilk total solids content (Liu and Chang, 2008). The method of soymilk preparation with a fixed water-to-bean ratio will decrease total solids content and accordingly results in a sharper decrease in optimal coagulant concentration than the method of soymilk preparation which adjusts water-to-bean ratio for keeping a fixed total solids content. Therefore, when a fixed coagulant concentration, which may be optimal for the freshly harvested soybeans, is applied to the soymilk made form the improperly stored soybean, the soymilk would coagulate too fast and form a poor curd (Liu and Chang, 2008).

2.1.6 Coagulation temperature and coagulation time

The temperature of soymilk at the time of adding a coagulant affects the coagulation rate as well as the tofu texture and yield. At a high temperature, proteins possess high active energy and fast to coagulation. The tofu tends to have small network, reduce water holding capacity, hard texture and low bulk yield. When the coagulation temperature is low, the effect is just the opposite. However, if the temperature is too low, (below 60 °C) the coagulation becomes incomplete, and the tofu contains too much water and is too soft to retain its shape. Therefore, selection of an actual temperature during tofu production depends on the type and concentration of coagulants, the mode of adding coagulants, and the type of tofu to be made. The optimum temperature range is 70-80°C. The tofu produce below 70°C is soft and watery whereas the tofu produce above 80°C is hard and uneven, with considerable loss of bulk yield (Beddows and Wong, 1987; Ohara et al., 1992).

After adding a coagulant, it is desirable to let the soymilk-coagulant system stands still for a while after a coagulant is added, since completion of coagulation requires a certain period of time. If the time is too short, coagulation is incomplete, if too long, the temperature of the system decreases to such extent that the subsequent molding step becomes difficult. In general, for silken tofu, the standing time should be about 30 min; for regular tofu, 20-25 min; and for firm tofu, 10-15 min (Ang et al., 1999).

2.2 Varieties of tofu

There are many different types of tofu on the market. Based on water content and textural properties, tofu is generally classified as soft (silken), regular, or firm tofu. Basically, all tofu is made in a similar fashion, except for variations in the water : bean ratio, the type and concentration of coagulants, the way a coagulant is added, and the amount of whey being pressed out.

2.2.1 Silken tofu

Soft or silken tofu has a soft cheeselike texture but is firm enough to maintain its shape after slicing. Silken tofu is normally made from rich soymilk containing 10-12 % solids. After being finely filtered, the soymilk is allowed to cool to 65-70°C. It is then mixed with a relatively low concentration of calcium sulfate. Over a period of 30-60 min, a fine, smooth, yet firm curd

forms. The curd is neither broken nor pressed. In China, silken tofu is normally made by pressing unbroken bean curds to remove some whey. This product has a soft texture but is firm enough to be cut into cakes and packed in containers with water. It is usually served in soups. The product is specially made by using low concentration of soymilk and a reduce amount of coagulant (Ang et al., 1999).

2.2.2 Regular and firm tofu

Regular and firm tofu are mostly pressed tofu, which are know as momen tofu. The difference between regular and firm tofu is that firm tofu is harder than regular tofu. Sometimes, the term extra firm is used by some manufactures. In any term, the textural difference among silken, regular, firm or extra firm is rather relative. There are no standard in absolute textural values for them and the texture of the same type of tofu may vary with manufacturers, seasons, and even batches. (Ang et al., 1999)

There are two basic features in making pressed tofu. First, the coagulant is stirred into hot soymilk and curds are thus formed upon cooling. Second, the curds are broken and then pressed while they are still warm. Also, the higher the pressure applied during pressing, the firmer is the tofu. As the texture becomes firmer, the water content becomes less. Firmer texture and reduced water content make tofu easier to handle and more similar to meat. Therefore, pressed tofu is ideal for use in pan-frying, deep-frying, grilling, freezing and then drying and dicing into an ingredient. (Ang et al., 1999)

2.2.3 Lactone tofu

When a tofu is made mostly with GDL, a modern coagulant, it is known as lactone tofu. The process starts with the preparation of rich soymilk (10-12 % solid content). The milk is heated and deaerated before cooling to about 30°C. Air bubbles form during milk production, and their presence affect tofu quality. This is particularly true for lactone tofu, which is characterized by a fine and smooth texture. Deaeration is carried out by passing heated milk to a vacuum evaporator, which not only reduces air bubbles, but also strips off some off-flavor volatiles. The cold soymilk is mixed with GDL at a concentration of 0.25-0.30% (based on the milk volume). The mixture is immediately run into a container and sealed. The container is then immersed in hot water (85-90°C) for 30-50 min for coagulation to occur. The resulting curd is cool in the container by immersing in cold water and then refrigerated. Lactone tofu also has three types

based on texture : soft, regular and firm. In most cases, lactone tofu is not made by GDL alone, but by a combination of GDL and calcium sulfate or magnesium chloride (Ang et al., 1999).

2.3 Tofu powder

Tofu powder is the product from ground dried tofu which can be used as an alternative protein source. Tofu powder is made from soybean by the traditional tofu method. Commercial coagulants are used as calcium salt, magnesium salt and acid. The tofu powder has a high protein and good essential fatty acid, linolenic and linoleic acid. The final moisture of tofu powder is low enough to inhibit microbial growth. No yeast and molds were isolated from the tofu powder. The low values for all the microorganism counts showed that the dried tofu powder after a storage period of 4 months under refrigeration was very stable (Ho et al., 1997).

The qualities of tofu powder are influenced by the method of tofu powder processing. Vilavan and Veerothai (1997) had prepared tofu powder by using calcium chloride or calcium sulfate as protein coagulants and drying in a hot-air oven. The solubility and emulsifying properties of tofu powder were not found to be as good as the commercial SPI.

The preparation of tofu powder has an effect on its quality. Panyathitipong and Puechkamut (2002) reported that $MgSO_4$ -tofu powder had significantly higher emulsion stability than $CaSO_4$ -tofu powder and $CaCl_2$ -tofu powder and found that whey separating methods and drying temperature were affected on functional properties and the yield of tofu powder. The emulsion stability of tofu powder obtained at 70°C drying temperature was greater and whey separation by centrifugation gave tofu powder at a higher yield and better emulsion stability compared to those of pressing method.

2.4 Utilization of soy protein and tofu powder in meat emulsion products

Meat emulsion products such as frankfurters, bologna are made from minced meat, water, salt and other ingredients such as phosphates, carbohydrates, non-meat protein and seasoning. The properties and quality of meat emulsion product depend on their processing and functional characteristics of salt soluble myofibrillar proteins which are extracted during ingredient mixing in the presence of salt. It was adsorbed at the product fat particle surfaces, due to their remarkable emulsifying ability (Drakos et al., 2005). The proteins in meat are coagulated during processing and cooking resulted the formation of a gel-like structure that binds muscle fibrils with the

emulsified fat particle, thus preventing liquid loosed and contributing to the development of the final product texture (Barbut, 1995; Lin and Mei, 2000).

Proteins from plant are often incorporated in meat emulsion products to improve their properties. In the meat industry, soy protein is most widely used the non-meat protein which is due to its biological value, its properties as an emulsifier, stabilizer and its capacity to increase water holding capacity (WHC). It has been used in the meat product as a binder for improving yields, as a gelling agent to enhance emulsion stability and as a meat replacer to reduce costs.

Some non-meat proteins can be used as fat replacers to bind water and to form gels, thus they respond to consumers demands for healthier and low fat products (Pietrasik and Duda, 2000). Moreover, there are also well known benefits associated with the consumption of soybean reduction of cholesterol levels and menopause symptoms and reduction of risk for several chronic diseases, cancer, heart disease and osteoporosis.

Soy protein possesses important functional properties that the constituents may interact with the meat protein in processed meat product. It appears that the properties of the system are dominated by the more functional salt soluble meat proteins while the soy protein play a rather secondary role (Mourtziou and Kiosseoglou, 2005). Mavrakis et al. (2003) reported that the texture of model comminuted meat product systems are enhanced by the presence of plant protein such as lupin seed protein indication that these proteins are involved in the development of the multicomponent comminuted meat gel structure during processing.

Feng and Xiong (2002) reported that preheated soy protein before mixed with myofibrillar protein resulted from unfolding of the protein molecules and the exposure of the hydrophobic parts of the soy protein complex. This resulted from myosin interacting with soy protein subunit due to hydrophobic aggregation between them, leading to the precipitation of heterogeneous protein aggregates that showed an improved gelling ability of their gel.

On a commercial scale, it is easier for using dry soy protein addition in meat process. However, in order to extend the functionality of soy protein in comminuted meat products, pre-emulsified fat (PEF) with soy protein as stabilizers has been employed. When PEF is used; meat proteins are saved for fat and water binding because part of the fat and water is stabilized completely by the soy protein due to the fat globules in the matrix were coated with a layer of protein membranes and dispersed in a dense protein matrix (Su et al., 2000). The fat globules contained in the protein food systems have been categorized as active or inactive filler particles depending on their interaction with the surrounding matrix (Gu et al., 2009). Active filler particles

are covered with protein and have mainly hydrophilic surfaces that interact with the matrix whereas inactive filler particles have mainly hydrophobic surfaces and show little interaction with the matrix (Chen and Dickinson, 1999). The protein membranes surrounding the fat globules are thick. When the fat globules are confined within the denser nonmeat protein matrix, the chances for fat coalescence during cooking may be reduced so that emulsions with high fat and water binding properties are formed (Su et al., 2000).

Lecomte et al. (1993) reported soy protein was incorporated in formulations of frankfurters as PEF and as powders. Sensory analysis showed the incorporation of soy protein as pre-emulsified resulted in a reduction of specific soybean off-flavor and off-aroma. Soy protein added as pre-emulsified increased water holding capacity and yield and decreased cook losses.

Lowering fat content in meat emulsion product must be equal in quality to traditional high fat products in order to be successfully marketed. Normally, reducing fat content in meat emulsion often negatively influences the quality of meat products. Incorporation of soy protein and hydrocolloid as gums and carrageenan into processed meat has been shown stabilize emulsion and increase water holding capacity that is a good quality of meat emulsion product (Luruena-Martinez et al. 2004).

Brewer et al. (1992) reported that the addition of soy protein decreased beefy flavor and increased off-flavor score in ground beef patties. This off-flavor and aroma make the products containing soy protein unpleasant to the consumer (Das et al., 2008). Soy protein has some disadvantages not only off flavor but also its manufacturing process is complicated and costly. Traditional soy foods such as soymilk and tofu can be substituted with soy protein as soy based products. Rahardjo et al. (1994) reported that spray dried soymilks were incorporated into reduced fat pork sausage. Spray dried soymilk mixtures had less fat and lower calorie content than regular pork sausage, protein content and cooking yield were higher than regular pork sausage. Texture of lean pork sausage was improved by addition of spray dried soymilk.

Tofu has the potential of being a satisfactory meat additive that can reduce the fat and calorie contents, if it is substituted for fat in meat emulsion products. Jeng et al. (1988) studied in which two levels (15.5% and 31.6%) of tofu were substituted for fat (12%-28%) and lean (3.5%) in making bologna, a comminuted meat type product. These treatments were compared with a meat batter containing 3.5 % soy protein concentrate and an all meat bologna. They found that bologna with tofu had a higher emulsifying capacity, less moisture stability, and lower fat and calorie level

than soy protein containing bologna. Moreover, the soy protein concentrate containing bologna had more beany flavor.

Tofu is quite perishable due to its rich nutrient and high moisture content. Its spoilage is associated with bacterial growth. While tofu powder is the product from ground dried tofu which can be used as the ingredient in processed meat products. Tofu powder can reduce fat content, improve texture and increase protein content without altering flavor in meat emulsion products (Ho et al., 1997). Panyathitipong and Puechkamut (2002) found that the emulsion made from tofu powder had good emulsion stability but the solubility of this tofu powder was very low. Ho et al. (1997) reported that regular frankfurter treated with tofu powder decreased fat with no significant differences in color, texture or overall acceptability compared to a control by sensory analysis. Lean frankfurter with tofu powder had lower moisture and color, better texture and overall acceptability with no flavor differences from controls. Lean pork sausage treated with tofu powder was lower in fat, higher in protein and moisture with no differences in sensory attributes compared to controls. Many researches, however, tried to use tofu powder on the supporting ingredients for processed meat products. The researches that aimed to use tofu powder as the main ingredient have rarely been done.

2.5 Utilization of hydrocolloid in meat products

Macromolecular hydrocolloids play a role in modifying the textural properties of food systems. They can be as gelling and thickening agent. The biopolymers interactions as protein-polysaccharide are importance to develop products with acceptable texture characteristics (Tolstoguzov, 1997).

Hydrocolloids are considered to influence many of the functional properties of processed meat products. They are commonly used in meat emulsion products as emulsifiers, water texture modifying ingredients (Chatotong et al., 2007), fat replacer (Cierach et al. 2009) to improve the functionality. Meat protein and polysaccharide interactions play a significant role in the structure and stability of meat emulsion products (Hua et al., 2003) due to their ability of binding water and forming gel (Candogan and Kolsarici, 2003). Functional properties of food proteins such as solubility, gel forming and emulsifying capacity are affected by their interaction with polysaccharide or hydrocolloid gums. Protein and polysaccharides can form hybrid complexes with enhanced functional properties in comparison with protein or polysaccharide alone. The gelation behavior of protein-polysaccharide mixtures generally fall into three patterns: formation

of covalent bonds between two polymers; polyanion-polycation electrostatic interactions; and formation of composite gel due to mutual exclusion of each component (Hua et al., 2003). Electrostatic complexation of oppositely charged protein and polysaccharide allows better anchoring of the newly formed macromolecular (Andres et al., 2006).

The anionic polysaccharide and protein could associate with each other through charge-charge attraction when the pH is below the isoelectric point of proteins, this interaction normally results in a precipitate of complexes, rather than formation of a gel. Most protein-polysaccharid mixtures are thermodynamically incompatible systems at neutral pH and the mixture can be separated into two liquid phases according to phase diagrams (Tolstoguzov, 1997). After gelation of the incompatible polymer mixture, the resulted gels could be regarded as filled of composite gels (Hua et al., 2003). Soy proteins and hydrocolloids have been used in meat emulsion products. They have been utilized often in modifying both the textural and sensory attributes of meat products (Flores et al., 2007).

Carrageenans are hydrocolloid that extensively use in food industry as gelling, thickening and stabilizing agent. Carrageenans and soy bean protein can be used together in food industry as gelling and viscous agents to improve textural (Ortiz et al., 2004) due to the synergistic effects between them (Baeza et al., 2002). The effect of carrageenan addition to meat emulsion products on sensory properties were increased for texture and acceptability with increasing carrageenan concentration (Cierach et al., 2009; Ayadi et al., 2009).

The microstructure of meat emulsion products can be observed by scanning electronic microscopy. The microstructure of meat emulsion products shows the meat proteins form a three dimensional compact gel network. When addition hydrocolloid as carrageenan or gum, it can forms a continuous gel network and suggesting that hydrocolloids is present in the interstitial spaces of the protein network which cause decrease in the compactness of protein network (Verbeken et al., 2005; Andres et al., 2006; Chen et al., 2007 and Ayadi et al., 2009).