CHAPTER 2

Literature Review

2.1 Papaya

Papaya is a well-known fruit worldwide for its benefit and flavour (Chaiwut et al., 2010). For Thailand, papaya is one of the important economic plants in the country that promote high agricultural products for domestic usages and import purposes that can grow in every part of the country (Rojsanga et al., 2014). It is a tree that can reach up to 9 m in height with hallow trunk and latex. The flowers are white with 5 waxy lobes and emerge from the leaf axils. Papaya is a sexually variable plant that can be divided as dioecious (male and female flowers on separate plants), monoecious (male and female flowers on the same plant) or hermaphroditic (having bisexual or "perfect" flowers). The fruits of this plant are berries with a tasty flesh and black seeds surrounded by gelatinous layer inside (Rojsanga et al., 2014). Papaya is a nutritive fruit. It is a good source of vitamins A and C (Cheenkachorn et al., 2012; de Oliveira and Vitória, 2011; Fernandes et al., 2006). Vitamin C (ascorbic acid) in papaya is higher than other tropical fruits, such as banana and pineapple, in the range between 35.4 and 187 mg per 100 g fresh weight (Udomkun et al., 2016). The fruit also contains several antioxidant compounds, bioflavonoids, minerals, digestive enzyme and fibers (Cheenkachorn et al., 2012; Udomkun et al., 2014) and is widely used in food diets based on their functional and digestive properties (Vivas et al., 2015). The common presence of these compounds that can act as functional components has increased the demand of the fresh fruit (Cheenkachorn et al., 2012). Papaya is a climacteric tropical fruit (Waghmare and Annapure, 2013), which can undergo a ripening process after harvesting. Following harvest, papaya will produce high ethylene that makes the fruit ripens and changes in the quality, such as modification in the flesh colour and the fruit texture or even softening (Khurnpoon et al., 2010). During ripening, the flesh fruit of

papaya endures softening due to biochemical changes in cell wall from the metabolism of pectin, hemicelluloses and cellulose of the wall (de Oliveira and Vitória, 2011; Phothiset and Charoenrein, 2011). Storage of the fruit has serious limitations, which results in their rapid deterioration and high incidence of rots. It is estimated that the papaya postharvest losses are mainly due to microbiological diseases (Dotto et al., 2015). According to Phothiset and Charoenrein (2011), the softening of papaya flesh fruit occurs quickly, which causes loss of quality and shortens its shelf life. Given the susceptibility of papaya to postharvest diseases is high, a careful management is necessary (Dotto et al., 2015). To overcome this, drying is one of the preservation methods that can increase the shelf life of papaya fruit by water removal to improve the quality and durability of the fruit (Cheenkachorn et al., 2012). Fresh and dried products from papaya fruit are highly required (Rojsanga et al., 2014).

Papaya trees spread widely throughout the tropics, mostly in Africa and Asia. The tree can grow in tropical and subtropical regions at temperatures between 21 and 33ºC. However, it does not tolerate cold weather of less than 15ºC. Cultivation of papaya is done in tropical Americas, India, Sri Lanka, various Asian countries and tropical Africa (de Oliveira and Vitória, 2011). Papaya tree is a soft-stemmed and unbranched tree that can grow to 20 m in high. It has large leaves that emerge directly from the upper part of the stem on long petioles (Moussaoui et al., 2001). The important papaya genotypes in the world include ‘Maradol’ that originates from Cuba and is widely cultivated in Mexico; ‘Sekaki’ and ‘Eksotika’ that are grown in Malaysia and ‘Khack Dum’ that is planted in Thailand (de Oliveira and Vitória, 2011).

One variety of Thai papaya was ‘Pluk Mai Lie’ papaya that was bred from ‘Red Maradol’ papaya cultivar from Mexico, which had firm flesh, preferable flavour and odour (Rojsanga et al., 2014). This variety has shown to have a great success in cultivation and has become a famous papaya for ripe consumption. The fruit of papaya ‘Pluk Mai Lie’ had a cylindrical shape that came from hermaphrodite flowers. The most marketable and mature of this papaya variety would be 3 months after flowering. At the proper edible stage, the ‘Pluk Mai Lie’ fruit peel was yellow to orange and the flesh is pale orange to red with sweet taste (11-14ºBrix) and a weak odorant (Fuggate et al., 2010; Rojsanga et al., 2014). Udomkun et al. (2014) reported drying papaya variety

‘Pluk Mai Lie’ from Nakhon Nayok province, Thailand using drying temperatures of 50 to 80ºC. Yousefi et al. (2013) investigated pretreated papaya slices in osmotic solution (50% sucrose) then drying at 40, 50 and 60ºC using conventional air drying. An increase in immersion time caused an increase in water loss, solid gain and weight reduction. For the drying process, drying time was decreased with an increase in drying temperature.

Figure 2.1 ‘Pluk Mai Lie’ papaya (เปรม ณ สงขลา, 2556)

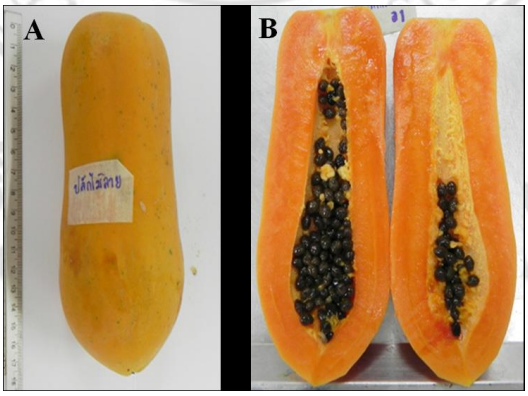

Figure 2.2 Physical characteristics of ‘Pluk Mai Lie’ papaya fruit; A = whole fruit, B = longitudinal section (Rojsanga et al., 2014)

2.2 Vacuum impregnation

Vacuum impregnation (VI) is a food preparation method that changes food composition. The VI process could be used to change various properties of food products, including physicochemical, nutritional, sensorial and shelf life characteristics

(Schulze et al., 2014). Applying VI into a porous tissue causes exchanging the internal gas or liquid normally contained in open pores for an external liquid phase (Fito et al., 2001; Occhino et al., 2011; Panarese et al., 2013). The technique has been shown to be highly effective for transferring compounds from an external solution into the food tissue (Perez-Cabrera et al., 2011). During a VI process, a product is immersed in a liquid tank and gone through two pressure steps. In the first step, a vacuum pressure is imposed on the system for a short time in the liquid tank, therefore promoting an expansion and outflow of the product internal gas. The releasing of the gas takes some of the product pore native liquid with it. In the second step, the atmospheric pressure is restored in the tank for a time and compression leads to a great volume reduction of the remaining gas in the pores and subsequently causing an influx of external liquid into the porous structure (Fito et al., 2001; Panarese et al., 2013; Zhao and Xie, 2004). Doing VI leads to a structural development of food tissue that differs from those, which are present in non-impregnated sample because of the substitution of air by an impregnation solution (Moreno et al., 2012). Impregnation of the external solution into food tissue is depended on the raw material characteristics, such as cell morphology, intercellular forces and pore diameters (Panarese et al., 2013). In addition, several factors that affect the effectiveness of VI process and the quality of finished products are tissue structure (pore and size distribution), vacuum pressure, relaxation time of the solid matrix, external solution/sample ratio, viscosity of the solution and size and shape of the sample (Zhao and Xie, 2004). After a VI process, impregnated products can be commercialised as minimally process fresh functional food products or can be further dried osmotically or by air in order to have better stability (Gras et al., 2003). The VI practise can also be used as a pretreatment before complementary processing steps, such as drying, freezing, canning and frying, and has an ability to modify food formulations and to develop new products (Zhao and Xie, 2004).

A study by Piromvard et al. (2010) investigated the impregnation of *Saccharomyces cerevisiae* and *Lactobacillus casei* in dragon fruit pieces using a VI condition of 50 mbar for 20 min. The result showed that the number of *S. cerevisiae* in the dragon fruit was higher than that of *L. casei*. At the same time, the studied microorganisms had a better survival rate when dragon fruit juice solution was used as an impregnation solution compared to that of sucrose solution. Another study by

Occhino et al. (2011) explored the application of VI to infuse different solutes composition, including maltrodextrines, NaCl and $CaCl_2$ in zucchini slices (0.5 cm thick). The VI was carried out at a vacuum pressure of 25 mbar for 10 min and a relaxation time of 30 min. The researchers found that the application of a mixed solution from the three solutes allowed to assisting solute and water gain with minimum textural and microstructure changes. Fresh apple had been investigated under VI using isotonic solutions of sorbitol, glucose, fructose, sucrose, trehalose and maltose solutions. Moreover, isotonic solution confirmed its positive effect on sensory analysis (Neri et al., 2016). VI technique seems to be feasible technologies for exploitations of fruit and vegetable tissues as new matrices into which functional ingredients can be successfully incorporated to provide a new product (Alzamora et al., 2005). An agreeable to this, Hironaka et al. (2011) studied the use of VI to enrich whole potato with ascorbic acid, in which 10% ascorbic acid solution were used. The results indicated that ascorbic acid concentration of whole potato increased with vacuum time (max 150 mg/100 g fruit weight).

2.3 Drying

Drying is the oldest method that is efficient and the most commonly use to preserve fruits and vegetables (Chen et al., 2015; Huang et al., 2016; Šumić et al., 2013). Currently, there are various types of food commonly used to be dried. Started raw material may be liquid, semi-solid or solid, while the final product is solid. This includes apple, nuts, carrot and milk (Orikasa et al., 2014). The final product may be pieces or powder that has different appearances and qualities depending on drying process and condition.

Water is one of the main food components that influences the shelf life of foodstuffs (El-Aouar et al., 2003; Fernandes et al., 2006). During a drying process, water is removed from a food product to reduce its water activity (Orikasa et al., 2014; Zhao and Xie, 2004). The technique has been widely used to extend the shelf life of fruits and vegetables and slow down the growth of microbial spoilage (Chen et al., 2015; Orikasa et al., 2014; Zhao and Xie, 2004). In addition, drying can also reduce the cost or difficulty of packaging, handling, storage and transportation by converting raw food into dry solid (El-Aouar et al., 2003; Orikasa et al., 2014).

Nowadays, dried products are popular with consumers due to their convenience. At the same time, an increase number of customers represent a challenge for food manufacturers to develop options in diversifying and accelerating food production. Drying is an important option that can reduce product weight, extend shelf life and broaden product availability (Jomlapelatikul et al., 2016). Another choice is intermediate food products. These food products are characterised by a moisture content of around 15–50% and a_w between 0.60 and 0.85 (Nopwinyuwong et al., 2010).

Drying performance must consider the quality of dried product because visual appearance is primary consumer decision, followed with nutritional to select their food (Udomkun et al., 2014; Yadollahinia et al., 2009). During a drying process, water removal induces changes of physical and chemical properties that both desired and unwanted such as colour that occurs from enzymatic or non-enzymatic browning (Erbay and Icier, 2010; Udomkun et al., 2014). After water removal from food tissues, size and shape or structural change can occur through shrinkage (Udomkun et al., 2014). Shrinkage occurs because structural deformation in shape and size of sample that occurs together with simultaneous heat and mass transfer. Food tissue cannot support and hence collapse in the absence of moisture (Aprajeeta et al., 2015; Kingsly et al., 2007). Unfortunately, drying process may lead to nutrient loss (El-Aouar et al., 2003). Vitamin C can be degraded, depending on many variables such as temperature, pH, light and time (Santos and Silva, 2008). For this reason, some researchers were interested to evaluate the stability of ascorbic acid in many fruits and vegetables, such as Demiray et al. (2013). These workers studied ascorbic acid degradation in tomato. Tomato quarters were dried at five different temperatures (at 60, 70, 80, 90 and 100ºC) in hot air drying. It was determined that drying temperature had a significant influence on the loss of ascorbic acid in the range of 0.076–0.472 h^{-1} from 60 to 70ºC. Comparing drying processes between hot air drying and vacuum drying, it was found that the residual ratio of ascorbic acid in kiwifruit was 0.75–0.88 and 0.90–0.99, respectively (Orikasa et al., 2014). To ensure that the quality and nutritional value of dried products are met the requirements, the application of optimum drying technology and condition is important. There are many factors that influence drying rate, such as food porosity, size and shape, quantity of food to be dried, drying technique, temperature, time and pressure (Crowley

and O'Mahony, 2016; Kurozawa et al., 2012). Moreover, drying selection must also consider energy efficiency as well.

For fruits containing sugar, it is required particular drying methods to decrease the water content. Drying vacuum impregnated fruits needs to consider factors that can cause undesirable changes. To produce high quality products, it is essential to avoid drying method with high temperature and long drying times (Schulze et al., 2014).

Hot air drying is widely used because of its simpleness and flexibility. However, there are some disadvantages of hot air drying, including time-consuming and a low energy efficiency, particularly during falling drying rate periods. The long drying time of the process causes degradation of product quality characteristics, such as colour, nutrient and flavour (Nimmanpipug and Therdthai, 2013; Orikasa et al., 2014). Vacuum drying is an alternative method, which is suitable for products that are sensitive to heat if it is exposed to high temperatures like fruits and vegetables (Chen et al., 2016; Laopoolkit and Suwannaporn, 2011; Šumić et al., 2013). In this method, moist food material is dried under sub-atmospheric pressure (Orikasa et al., 2014). Drying by a vacuum dryer can have a high drying rate because the boiling point of water in the product, which is held under vacuum, is lower than atmospheric pressure and water vapour is removed by a vacuum pump (Artnaseaw et al., 2010). Beside a high drying rate, the vacuum drying has characteristics of low drying temperature and oxygen-deficient drying environment, which may give an advantage to prevent oxidation since food sample will not contact with air during the drying process. This condition can maintain qualities of dried food sample, including colour, shape, aroma and flavour and nutritive values. Furthermore, this drying technique can have energy saving (Artnaseaw et al., 2010; Orikasa et al., 2014; Šumić et al., 2013; Torres et al., 2011).

Betoret et al. (2003) studied about impregnation of apple pieces with apple juice containing *L. casei* spp. *rhamnosus*. The apple samples were then dried for 48 h with an air dryer at 40ºC under a flow rate of 4 m/s. The finding showed that the content of *L. casei* viable cells in the dried and stored product at 8ºC for six days was greater than 10^6 cfu/g. The investigation about hot air drying and vacuum drying of kiwifruit slices had been carried out by Orikasa et al. (2014). These workers applied drying temperatures of 50, 60 and 70ºC and a vacuum drying pressure of 3.0 kPa. It was found that vacuum

drying could preserve ascorbic acid better than that of hot air drying. Kurozawa et al. (2014) investigated the degradation of ascorbic acid during hot air drying of papaya cubes at air temperatures of 40, 50 60 and 70ºC. The results showed that the lowest temperature had higher retention of ascorbic acid. According to the study of dried tomato, the lowest temperature of 60ºC could retain ascorbic acid degradation better than high temperatures of 70, 80, 90 and 100ºC (Demiray et al., 2013). Doing vacuum drying for frozen sour cherries showed that drying temperatures gave slight influence on vitamin C content in the fruit, but an increase in drying pressure caused a decrease in vitamin C content (Šumić et al., 2013).

2.4 Lactic acid bacteria

An increase in consumer awareness for healthy diets and changing eating habits has created a huge market demand for functional food products, which can deliver a beneficial effect on health. Functional foods beneficially affect one or more target functions in the body, to support health and well-being or reduce the risk of disease (Alzamora et al., 2005). At present, the consumption of probiotic cells through food products is more popular than that through dietary supplements, such as in the form of powders, capsule or table forms (Rathore et al., 2012; Tripathi and Giri, 2014). Although probiotics in dairy products, including yoghurt and milk powder, are widely available in the commercial market, consumer demand for non-dairy based probiotic products has risen. This demand can be solved through fruit products. Naturally, fruits are rich in functional food components, for example minerals, vitamins, dietary fibers and antioxidants. Fruit also does not contain any dairy allergens that may prevent its use by some segments of the population and suitable for vegetarian (Yoon et al., 2006).

Probiotic has been defined as live microbial food ingredients when administered in adequate amounts confer a health benefit on the host or as live microbial food supplements, which beneficial affect the host by improving the intestinal microbial balance (Betoret et al., 2003; Betoret et al., 2012; Tripathi and Giri, 2014; Yoon et al., 2006). Research results have shown that probiotics provide several health benefits, including protection against gastrointestinal pathogens, anti-carcinogenic activity, reduction in the level of serum cholesterol, improved gastrointestinal function, enhanced immune system and lower the risk of colon cancer (Tripathi and Giri, 2014;

Yoon et al., 2006). Generally, probiotic microorganisms for human consumption are in the genera of *Lactobacillus* and *Bifidobacterium*, including *Lactobacillus plantarum*, *L. casei* and *Lactobacillus acidophilus* (Argyri et al., 2013; Betoret et al., 2003; Tripathi and Giri, 2014; Yoon et al., 2006). These lactic acid bacteria are natural components of the normal intestinal microbiota in human (Signorini et al., 2012). Although some probiotics have been marketed in several dairy products, the problems of lactose intolerance and cholesterol content have tampered their consumption by some people in the society (Betoret et al., 2012; Yoon et al., 2006). For fruits and vegetables, Betoret et al. (2003) and Betoret et al. (2012) have proposed a technique of vacuum impregnation to incorporate probiotic microorganisms and/or minerals in the fruit and vegetable structures.

To deliver its health benefits, scientific evidence suggested that probiotic bacteria should be consumed at high levels (10^9-10^{10} cfu/day) to be able to decrease the incidence, duration and severity of some intestinal illness (Betoret et al., 2012). This level of consumption meant that the minimum level of the probiotic content in a food product should be more than 10^6-10^7 cfu/ml (g) at the end of the food shelf life or at the consumption time (Argyri et al., 2013; Betoret et al., 2003; Betoret et al., 2012; Dimitrellou et al., 2016; Mårtensson et al., 2002). US Food and Drug Administration has also recommended the minimum probiotic count in a probiotic food product should be at least 10^6 cfu/ml (Tripathi and Giri, 2014). Depending on amount ingested and taking into account the effect of storage on probiotic viability, a daily intake of 10^8-10^9 probiotic microorganisms is considered essential to achieve probiotic action in human (Tripathi and Giri, 2014). This is consistent with Dimitrellou et al. (2016), who suggested that delivery of 10^9 viable probiotic cells to the intestine is necessary to achieve a probiotic action. Besides having a sufficient number of probiotic at the time of consumption, the probiotic food product should also be safe.

Mostly, probiotic products in dairy or food industry were in wet form with low storage temperature to prolong shelf life (Dimitrellou et al., 2016). In some cases, drying process can be considered to be applied. Probiotic food products can sometimes be dried to increase their shelf life at ambient temperature and to reduce the cost of frozen storage. Drying can also stabilise probiotics for their ease of storage, handling,

transport and subsequent use in functional food applications. During drying of probiotic food products, it needs to minimise the loss of probiotic viability (Tripathi and Giri, 2014). An optimal drying condition can maintain the activity and survivability of the probiotic that depend on the operating technique such as drying temperature, carrier materials and other storage conditions (Kingwatee et al., 2015). The survival of two lactic acid bacteria in orange powders obtained by hot air drying at 40ºC for 48 h showed a reduction of 2 log cycles from 8 to 6 log cfu/g. In addition *L. plantarum* could have better viability than *Pediococcus acidilactici* (Barbosa et al., 2015). The study of Kingwatee et al. (2015) showed that *L. casei* in lychee juice could tolerant temperatures up to 80ºC with a spray drying technique and the survival cells was reached up to 5 or 6 log cfu/g. Therefore, if VI is combined with hot air drying, it is possible to create a new functional product for more consumer choices (Castagnini et al., 2015). Applying a hot air drying to an impregnated apple with mandarin juice containing *Lactobacillus salivarius* resulted in a 1 log fold reduction in microbial content from 1.51 x 10^8 cfu/g of impregnated sample to 9.5 x 10^7 cfu/g of dry sample (Betoret et al., 2012).