CHAPTER 2

LITERATURE REVIEW

Longan fruit is one of the major produce exports of Thailand and a non-climacteric subtropical fruit which is classified in the family of Sapindaceae that also include litchi and rambutan (Tongdee, 1997). Longan (*Dimocarpus longan* Lour. cv. Daw) is mostly cultivated in the northern part of Thailand, especially Chiang Mai and Lumphun provinces. There also exists the cultivation area in the eastern part of Thailand, for example, Chanthaburi province (OAE, 2009). Good Agricultural Practice (GAP) orchards of 100,000 farmers are currently registered by the Department of Agriculture (DOA) of the Ministry of Agriculture and Cooperative (MOAC) for quality control purposes before exportation. Production and harvested area in 2008 were 1,035,556 and 966,831 Rai, respectively, with the overall production capacity of 476,930 tons (OAE, 2009). Thirty percents of the total produce was consumed domestically. The rest was exported as fresh fruit or in the forms of frozen and dried longan. The values of dried longan flesh and other processed products were 4,000 million baht. Thailand was ranked as the second highest longan producer in the world which was superseded only by China. However, the country was the first runner in term of longan export. The net fresh and frozen exports of longan fruit tallied at 149,919 tons (2,350 million baht). OAE (2009) reported the major importer of fresh longan are China with other countries such as Hong Kong, Singapore, Indonesia, EU, Canada, and USA.

Commercial cultivation of longan fruit has been in many countries including China, Thailand, India, Viet Nam, Australia, and U.S.A. (Jaitong, 2001). The fierce export competition of longan fruit was between Thailand and Viet Nam, the second runner-up (Tongdee, 1997). Figures 2.1 and 2.2 show longan tree at the orchard and fresh longan fruits, respectively.

Figure 2.1 Longan tree at the orchard.

Figure 2.2 Fresh longan fruits.

The produce of fresh longan is about 500,000 tons per year covering about 2-month period. Not all of them can be sold as fresh longan. Fresh longan of about 300,000 tons must be dried to extend the shelf life. At present, there is no specific moisture tester for dried longan aril.

2.1 Moisture content in terms of electrical capacitance and dielectric constant

Jorgensen *et al.,* (1970) found that one of the factors that affect the deterioration of dried agricultural product is moisture content. It is the major factor affecting quality and price of dried longan. The moisture content of dried longan must not exceed 13.5 % Wb (wet basis) of the whole fruit or 18 % Wb of aril (National Bureau of Agricultural Commodity and Food Standard, 2005). Presently, there is no specific instrument for moisture content measurement in dried longan. Farmers can subjectively estimate the moisture from surface of skin, aril, and seed by their experiences. In general, there are two methods of moisture content measurement including a direct method and an indirect method. A standard direct method is to use a hot air oven but it takes a long time. An indirect method is to use electrical techniques that measure electrical properties. Pace *et al*., (1968); Nelson, (1972); Nuri (1992) found that electrical properties of frequency wave were also affected by moisture content, density, and temperature of medium**.** Kaewrawang *et al*. (2007) studied on electrical permittivity of lemon, pineapple and apple. They found that the complex permittivity of fruits depended on the operating frequency of electromagnetic wave and the aging of fruit. The best range of frequency was between 20 kHz and 100 MHz for the best discrimination. Accordingly, the determination of capacitance is an indirect moisture content measurement for products. This method is convenient, quick and accurate. The principle of capacitance measurement is shown in figure 2.3.

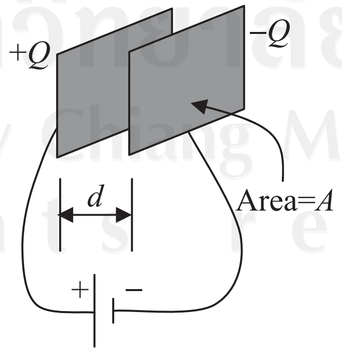

Figure 2.3 Principle of capacitance measurement.

The determination of capacitance can be done by using signals which has two approaches: frequency wave and signal pass wires. The signal pass wires are more popular for measuring the value of moisture than the frequency wave which is used to test other quantities, such as density, sweetness, etc.

Dielectric properties of various agri-foods and biological materials are finding increasing application, as fast and new technology is adapted for use in their respective industries and research laboratories. Debye (1929) reported on polar dielectrics and odeling studies date back more than 70 years. Early measurements of food dielectric properties were published by Dunlap and Makower (1945) for carrots at frequencies in the range of 18 kHz to 5 MHz. The dielectric constant and conductivity were reported to depend largely on moisture content as influenced by frequency, temperature, density and particle size. The main reason for their study was to investigate the behavior of a high moisture commodity, such as carrots, over the frequency range from 18 kHz to 5 MHz. The dielectric constant was essentially constant at moisture content up to 6 to 8 % and increase rapidly at higher moisture; similar behavior was seen for measured conductivities. Their results suggested that higher frequencies were most suitable for moisture determination in food products. Knipper (1953) reported that the first moisture meter was designed and developed in the former U.S.S.R. for barley and wheat moisture measurement. However, no quantitative data were reported (Von Hippel, 1954).

Pace *et al*. (1968) considered the potential for microwave finish drying of potato chips and found that energy absorption at 1.0 and 3.0 GHz increased at higher moisture contents and temperature. Thompson and Zachariah (1971) found that dielectric properties of apples at frequencies of 300 to 900 MHz varied with maturity, and dropped in the process of aging. Nelson (1972) measured dielectric of oats in different bulk density at 1 to 20 kHz and found that dielectric had a linear regression with bulk density. He an applied electrical frequency from 1 to 50 MHz in wheat, corn, oats, and barley and found that when moisture content increased, dielectric value increased. However, when frequency decreased, the dielectric increased.

Tran *et al*. (1984) tabulated the dielectric properties of selected vegetable and fruits at a frequency range of 0.1 to 10 GHz. For grain products, an indirect method can determine accurately in the ranges of 7 to 17 % Wb for electrical resistance and 6 to 21 % Wb for capacitance. The measurement of dielectric properties and capacitance has gained importance because it can be used for non-destructive monitoring of specific properties of materials undergoing physical or chemical changes. A moisture content measurement system for grains was proposed based on dielectric properties.

Koro (1993) investigated the relationship between density, volume and mass of melons by applying electrical frequency of 1 MHz in order to measure the capacitance, and corresponding density. This method was relatively accurate with the associated error level of 0.4% in comparison with the standard method. Tong *et al*. (1994) studied the dielectric of pea puree using electric frequency varied from 915 MHz to 2545 MHz and the temperature between 25 to 125 °C .He found that the dielectric constant decreased when temperature and frequency increased. Ryynanen (1995) studied the dielectric properties of the material affect the capacitance. In the mean time, the moisture of the material affects the dielectric constant. The moisture of the material is in direct proportion to the dielectric constant. Accordingly, the determination of capacitance is an indirect moisture content measurement for products**.**

Nelson (1991) found that earlier concept of permittivity measurements was based on dc electrical resistance to determine grain moisture content. A non-linear increase in resistance of the grain as temperature decreased gave useful observations. Later on, ac measurements were commonly employed to measure the change in capacitance and suitable sample holding capacitors were developed. Nelson (1998) studied on grain moisture measurement based on dielectric properties data became the most prominent agricultural application. Newer instruments and their calibration led to the development of a standard-oven technique which further contributed to several applications of radio-frequency dielectric heating and supplemented the quest for more quantitative values.

Samir Trabelsi *et al*. (1998) employed a nondestructive microwave characterization technique for simultaneous determination of the bulk density and moisture content of shelled corn. This method considerably simplified the calibration procedure as it was applicable to a number of measurement technique. Calibration equations for the bulk density and moisture content were constructed with the standard error of performance (SEP) at several frequencies in the range of 11 to 18 GHz for 14, 24 and 34ºC. The bulk density within the range of 695 to 830 kg/m^3 could be determined with SEP span of 11 to 15 kg/m^3. Neither the moisture content nor temperature level was required in order to determine the bulk density. The moisture content ranging from 9% to 19% Wb, could be determined at each temperature without knowledge of the bulk density with SEP of less than 0.5% moisture content. Results from an error analysis also indicated fifty percents of uncertainties in bulk density and moisture content could be classified as systematic errors which were correctable.

Berbert *et al*. (2002) found that the dielectric properties of common bean increased with moisture and bulk density and decreased with frequency. Sharma and Prasad (2005) reported that dielectric of garlic (*Allion sativum L.*) had linear regression relationship with temperature and dielectric was a function of moisture content and temperature at the frequency of 2 MHz. Guo *et al*., (2008) studied the dielectric constant of chickpea flour and loss factor was found to increase with higher temperature and moisture content.

Kamil *et al*. (2007) elucidated the dielectric properties of safflower seeds over the electrical frequency range of 50 kHz to 10 MHz with moisture content in a range of 5.33–16.48% Db. The bulk density of these seeds varied between 553.6 and 638.8 kg/m^3 using parallel-plate capacitor sample holder. The dielectric constant was directly proportional to moisture content and bulk density. This was in contrast with frequency where the inverse proportionality between the dielectric constant and frequency was observed. The dependence of the dielectric constant on frequency and moisture content was more regular than that of the loss factor.

Singh *et al*. (2007) investigated the dielectric properties of poppy which was considered pharmaceutically important as the seeds could be used for extracting opium, a basic compound of various medicines. The electrical frequency range of 5 kHz to 10 MHz was applied between 15 to 45ºC. The dielectric constant and loss had been found to elevate with the increasing moisture contents.

Kaewrawang *et al*. (2007) reported electrical permittivity of lemon, pineapple, and apple. The complex permittivity of fruits strongly depended on the operating frequency of electromagnetic wave and age of each fruit. The best frequency range was between 20 kHz and 100 MHz.

Chusak *et al*. (2008) studied on resistance type moisture meter for dehydrated longan fruits and developed the moisture meter for dehydrated longan with whole longan. Fifteen seedless and peeled longans were measured the electrical resistance then calculate to moisture content. The meter operated on the moisture content in the range from 60% wb to 10 % wb.

An example of the commercial moisture measurement systems is the moisture tester model 465 by Vomax company (2009) that measures the moisture of dried products like nuts and cotton using a low power radio frequency resonance technique.

The dielectric properties of agricultural and food material (product) have been principally used for predicting heating rate describing the behavior of materials when subjected to high frequency or microwave electric fields in dielectric heating applications and as indication in their use for rapid methods in the development of appropriate techniques for moisture determination (Nuri, 1981). In the last 10 to 15 years, the concept of permittivity measurement has been extended and applied to various agricultural, food, and bioresource problems. Research and development in this area need to be intensified. The main objective of this overview paper is to discuss various methods of measurement (and principles) of dielectric properties and their applicability for agri-food and biological materials.

2.2 Moisture content in term of water activity

Water activity (a_w) is a measurement of water content. It is defined as the vapor pressure of water divided by that of pure water at the same temperature; therefore, pure distilled water has a water activity of exactly one Water activity is defined as the amount of water available for microbial (bacteria, yeast and mold) growth. Water activity is based on a scale of 0 to 1.0 with pure water having a water activity of 1.00. Usually products that contain lower percent moisture have lower water activities. For example, those products such as dried fruits, crackers and dried pastas have very low water activities. Those foods with lower water activities are quite shelf-stable in that they contain very little water available for microorganisms to use for growth. When microorganisms grow, they degrade the food causing spoilage as well as health dangers for the consumer (Karel *et al*.,1975).

Although there can be a correlation between total moisture content of a food and the water activity, the correlation does not occur at all times. Food products can exist with high moisture content but have very little water activity. Many natural ingredients can be added to a product to "bind" the water making it unavailable for the growth microorganisms. Several common ingredients the bind water are sugar, salt (has six times the capacity to bind water when compared to sugar), pectin and glycerol. A good example of a food product that contains a good deal of water with a fairly low water activity is jelly. Although composed of 50 to 60% water, jams usually have water activities around 0.75. The sugar and pectin in jams binds the water making it unavailable for microbial growth.

Beuchat (1981) found that the moisture content of dried fruits containing 15 to 20 % wet basis have water activities 0.600. For most foodstuffs, this is in the range of 0.6 to 0.7 a_w. In general, dehydrated foods have a_w's less than 0.6; semi-moist foods, such as cereal grains, raisins, dates, syrups, and intermediate-moisture pet foods usually have a_w between 0.62 and 0.92. Cheeses, jams, jellies, meat, fish, etc. have a_w's greater than 0.92. Thus, with knowledge of the moisture sorption isotherm, we can predict the maximum moisture that the food can be allowed to gain during storage. Feng *et al*. (2002) studied the range of a_w lies between 0.0 and 1.0. The level of a_w below 0.6 prolongs the shelf-life storage of many products such as dried food, grain, dried milk, and coffee as the remaining water content in these food was insufficient to support bacteria growth. Lapsongphol *et al.* (2010) found that the moisture content of dried longan aril with about 16 % wet basis had water activities of 0.597.

2.3 Prediction models

There have been many research works in the area of system identification of a nonlinear black-box model. One of the most popular classes of artificial neural networks is the Multilayer Perceptrons (MLP) with the backpropagation algorithm as the training method. The MLP have been applied to several areas, for example, agriculture (Effendi *et al.*, 2010), medicine (Benamrane *et al.*, 2005; Isa *et al.*, 2007; Eiamkanitchat *et al.*, 2010), face recognition (Rizon *et al.*, 2006), electric power systems (Benslimane, *et al.*, 2006), etc.

The Support Vector Machine (SVM) is one of the most successful algorithms based on the statistical learning theory (Vapnik, 2000; Christiani and Taylor, 2000). It was originally developed to solve classification problems but recently extended to the domain of regression problems known as the Support Vector Regression (SVR) (Gunn and Brown, 1999). One of the advantages of the SVM is that it has a few free parameters to adjust and solving for its optimal model parameters can be achieved using any standard quadratic programming algorithms. This can be done in a short time and there is no local minimum. It is a powerful technique for solving the nonlinear function approximation problems. Moreover, the Structural Risk Minimization (SRM) in learning SVM algorithm is more powerful than the Empirical Risk Minimization (ERM) in the MLP. It has been shown in several applications that both SVR and MLP provided better regression performance than the linear regression and polynomial regression, e.g., in flood prediction (Theera-Umpon *et al.*, 2008), electric load forecasting (Pahasa and Theera-Umpon, 2008; Abd, 2009), drug concentration estimation (Sumonphan *et al.*, 2008), power systems (Boonprasert *et al.*, 2003), computer networks (Hasegawa *et al.*, 2001), telecommunications (Suyaroj *et al.*, 2010), finance (Song *et al.*, 2010), environment (Mileva-Boshkoska and Stankovski, 2007).