

# CHAPTER 1 INTRODUCTION

## 1.1 Motivation

*Brassica* vegetables, including broccoli, kale, cauliflower and white cabbage, have been reported to have beneficial effects in reducing the risks of coronary heart disease, cardiovascular disease and hypertension (Podsędek, 2007). These vegetables contain high amount of dietary fiber (DF) (Jongaroontaprangsee et al., 2007; Nilnakara et al., 2009) and phytochemicals with antioxidant and anticarcinogenic activities (Singh et al., 2006).

The major antioxidants contained in *Brassica* vegetables are phenolic compounds, vitamin C, vitamin E and  $\beta$ -carotene (Singh et al., 2006; Kaur et al., 2007). Antioxidants play important role in preventing diseases and maintaining health by reducing or preventing the oxidation of other molecules by inhibiting electron transferring from substance to oxidizing agent (Porkorny et al., 2001).

Glucosinolates, a group of sulfur containing plant secondary metabolites, are also found in *Brassica* vegetables (Chen and Andreasson, 2001; Volden et al., 2008). It has been reported that glucosinolates and their breakdown products possess anticarcinogenic activity (Fahey et al., 2001). Glucosinolates can be hydrolyzed by myrosinase, which is located in plant cells and intestinal microflora in human, to form different products, e.g., thiocyanates, isothiocyanates, epithionitrile, nitrile and oxazoidine-thione (Wennberg et al., 2006). The breakdown products, especially isothiocyanates, possess anticancer activity via modulation of phase II enzymes, including glutathione S-transferase and quinone reductase. These enzymes are reported to help inactivate cancer by blocking

normal cells from DNA damage (Verkerk et al., 2001). Sulforaphane, which is a type of isothiocyanates, is claimed to be the most potent anticarcinogenic activity.

Losses of phytochemicals usually occurred during processing. The water soluble phytochemicals such as vitamin C are susceptible to heat and may also lose during blanching (Davey et al., 2000; Ismail et al., 2004; Singh et al., 2007). Several reports have shown that antioxidants decreased during blanching because of enzymatic breakdown, thermal breakdown and leaching into blanching water (Wachtel-Galor et al., 2008; Cartea and Velasco, 2008). For example, Ismail and Lee (2005) found that longer blanching time resulted in a significant reduction in phenolic contents and antioxidant activity of red and white cabbages. Mrkic et al. (2006) showed that higher drying temperature (50-100 °C) resulted in higher losses of phenolic compounds and ascorbic acid in broccoli. Loss of glucosinolates was also observed during blanching. Approximately 47-65% reduction in glucosinolate content has been reported for broccoli after blanching in hot water (98 °C) for 2 min (Jone et al., 2006). Wennberg et al. (2006) reported that 50-74% reduction in the glucosinolate content occurred after blanching white cabbage in boiling water for 5 min.

Drying can also often cause significant losses of antioxidants in fruits and vegetables (Porkony et al. 2001; Garua et al., 2007; Ball, 2006). Mrkic et al. (2006) studied the effect of drying temperature (50-100 °C) on phenolic compounds and ascorbic acid in broccoli. It was observed that higher drying temperature resulted in higher losses of phenolic compounds and ascorbic acid. Katsube et al. (2008) studied the effect of air drying temperature (40-100 °C) on the antioxidant capacity and the stability of phenolic compounds in mulberry leaves. Their results showed that the antioxidant capacity and

phenolic compounds significantly decreased when drying at the temperature higher than 70 °C. The degradation of hot air glucosinolates was also observed during drying. Mrkic et al. (2010) studied the effect of temperature (50-100 °C) of the air that was used to dry broccoli and reported that glucosinolate content decreased upon drying, especially at higher temperatures.

Drying method is another factor affecting bioactive compounds in dried fruits and vegetables. Gong et al. (2007) studied the retention of vitamin C in cabbage after drying by different methods (air drying, vacuum drying and freeze drying). They found that drying method had a significant effect on vitamin C content and air dried cabbage had the lowest retention of vitamin C.

It has been reported recently that there is a potential to transform the outer leaves of white cabbage (*Brassica oleracea* L. var. capitata), residues usually discarded during industrial preparation or before selling in a consumer market, into DF powder. Jongaroontaprangsee et al. (2007) produced high DF powder from outer leaves of cabbage via the use of hot air drying at 60-80 °C and reported that the powder contained approximately 41-43% total DF (dry basis). The powder possessed high water holding capacity and swelling capacity making the product attractive for many food applications. Nilnakara et al. (2009) further studied the effects of hot-water blanching and hot air drying temperature (70-90 °C) on the quality of DF powder produced from cabbage outer leaves. Their results showed that the DF powder prepared by blanching sample into hot water prior to drying at 80 °C could retain the highest total phenolic content, vitamin C and total antioxidant activity. Although guidelines for production of DF powder from cabbage are available, there was still a need to determine effects of

each processing steps on the evolutions of antioxidants of interest as these compounds are heat and oxygen sensitive and may be degraded during processing. Furthermore, the data on the evolutions of glucosinolates as well as sulforaphane, the important anticarcinogenic substances, had not been established. Therefore, the effects of each processing steps must be well determined to produce DF powder associated with both antioxidant and anticarcinogenic activities.

Besides producing DF powder to add value to the by-product, extraction of phytochemical compounds from white cabbage was proposed in this work. Among many phytochemical compounds contained in white cabbage, sulforaphane is the most interesting compounds since the compound possesses the most powerful anticancer activity (Shen et al., 2010).

Extraction of bioactive compounds from food matrix can be conducted using various methods. One possible way is the use of microwave-assisted extraction (MAE) as this method has been reported to largely reduce the extraction time and increase yields of extracted compound (Dai et al., 2010). Charalampos and Komaitis (2008) compared MAE and conventional (reflux) extraction of phenolic compounds from aromatic plants. Their results showed that MAE provided shorter extraction time, required less solvent volume and gave higher yield than conventional extraction. The extraction efficiency can be influenced by many factors such as types of solvent, extraction time and microwave power (Liazid et al., 2011). To effectively extract compound from plant cells, there is a need to determine the effect of extracting parameters on yield of extracted compound.

The overall aims of this thesis were studying the effects of processing steps, i.e., blanching, drying methods and conditions, on the retention of antioxidants and glucosinolates during production of high DF powder as well as on sulforaphane formation and degradation. MAE of sulforaphane was also investigated. Cabbage outer leaves were used as a raw material.

This thesis consists of 7 chapters. This chapter (Chapter 1) describes the problem leading to the dissertation. Literature survey which includes the general information of white cabbage, phytochemicals in fruits and vegetables, DF, production of DF powder, drying, pretreatment, effect of processing on phytochemicals as well as MAE are given in chapter 2. The results and discussion of the work are divided into 4 chapters (Chapter 3 to Chapter 6). Chapter 3 details the effects of processing on antioxidants in DF powder from cabbage outer leaves. The changes of total glucosinolates during DF powder processing are described in Chapter 4. Chapter 5 provides the effects of processing on formation and degradation of sulforaphane. In Chapter 6, the study of feasibility of using MAE to extracted sulforaphane from cabbage leaves is also described. The final chapter (Chapter 7) summarizes the conclusions and contribution to knowledge obtained from this work, and provides recommendations for the future works.

## 1.2 Objective

1. To study the effects of processing steps on the changes of antioxidants and glucosinolates during production of high DF powder from cabbage outer leaves.
2. To study the effect of processing step on sulforaphane formation and degradation.
3. To study feasibility of using microwave extraction of sulforaphane from white cabbage.

## 1.3 Scopes

1. Studying the effects of preparation steps, i.e, slicing, and blanching methods, i.e., blanching in hot water and steam blanching on the evolution of phytochemical contents in terms of phenolic compounds, vitamin C, vitamin E and  $\beta$ -carotene, total antioxidant activity and total glucosinolates.
2. Studying the effects of drying methods, i.e, hot air drying and vacuum drying and drying conditions at temperatures of 60, 70 and 80 °C on the evolution of phytochemical contents in terms of phenolic compounds, vitamin C, vitamin E and  $\beta$ -carotene, total antioxidant activity and total glucosinolates.
3. Studying the effects of preparation steps, i.e, slicing, and blanching methods, i.e., blanching in hot water and steam blanching and hot air drying (40-70 °C) on evolution of sulforaphane during drying and developing a mathematical model to predict changes of sulforaphane during drying.
4. Studying the use of microwave for extracting sulforaphane. The extracting parameters such as type of solvents, i.e, dichloromethane and water, microwave power (130, 260 and 390 W) and extraction time were investigated. A comparison between extraction yield obtained by microwave extraction and conventional extraction was also determined.

#### **1.4 Expected benefits**

1. An understanding of phytochemical changes during processing which can be used for developing a suitable DF powder production process from cabbage residues.
2. The information obtained would be used as guidelines for extraction of sulforaphane by microwave.