

1. INTRODUCTION

1.1. Background

Chilli peppers are widely used as spice and condiment. Chilli peppers can also be consumed as fresh or cooked (Wahyuni et al., 2013). In food industries, chilli peppers are usually used as a colourant, flavourant, sources of pungency (Nadeem et al., 2011), antioxidant, and also as antimicrobial compounds (Gurnani et al., 2015).

Many kinds of processing methods which are usually performed on chilli pepper are drying (Iqbal et al., 2015; Toontom et al., 2016; Hossain et al., 2007), boiling (Shaimaa et al., 2016), roasting (Hwang et al., 2012), microwaving (Chuah et al., 2008; Roy, Pal, & Bhattacharyya, 2014), stir-frying (Hwang et al., 2012; Chuah et al., 2008), pressure cooking (Roy et al., 2014) and grilling (Ornelas-Paz et al., 2010). To maintain the shelf-life of chilli peppers, low-temperature treatment by freezing is also necessary during storage (Iqbal et al., 2015).

Capsaicinoid is responsible to provide hot and pungent taste (González-Quijano et al., 2014; Giuffrida et al., 2014). Capsaicin, dihydrocapsaicin and other similar compounds are called capsaicinoid. The major components of capsaicinoid are capsaicin, followed by dihydrocapsaicin. Capsaicin is a flavourless and odourless component. Capsaicin can be used in food industry and pharmaceutical industry (Reddy & Sasikala, 2013; Srinivasan, 2016). Capsaicin and dihydrocapsaicin are components of capsaicinoid that contribute to more than 95% of the pungency flavour (Zhou & Goh, 2005). When chilli pepper begins to ripe, the capsaicinoid is starting to accumulate in the epidermis cell of the placenta (Wahyuni et al., 2013). The pungent flavour of chilli pepper made it very popular and become the determinant of quality for consumers. The pungent flavour will be reduced during cooking or processing (Tunde-Akintunde, 2010; Ornelas-Paz et al., 2010; Toontom et al., 2016).

In addition to pungency and flavour, physical properties such as colour, texture and some nutrient contents can be affected by processing (Heredia-Léon et al., 2004). The flavour, pungency, and colour of chilli peppers are attributed to determine the quality of chilli peppers. Maintaining the colour of chilli peppers during the thermal process is a challenge in food processing (Ahmed et al., 2002). The red colour of ripe chilli peppers is related to the carotenoid. Capsanthin and capsorubin (an isomer of capsanthin) are the major pigments that contribute to the red colour intensity (Wahyuni et al., 2013).

Chilli peppers are usually used as a spice in any kinds of food. The unique taste of chilli pepper makes this fruit is very popular especially in Asia. Many Asian people love to eat spicy food. Many kinds of Asian cuisine contain chilli pepper. Western people also consume less pungent chilli pepper (paprika) as their dish and as a spice. Beside of the taste, there are a lot of health benefits that contained in chilli pepper because of the natural antioxidants (Embuscado, 2015). The antioxidant can help to prevent cardiovascular disease, cancer and also diabetes (Bahorun et al., 2004). According to Moure et al. (2001), natural antioxidant frequently shows lower antioxidant activity than the synthetic ones, however, Embuscado (2015) said that natural antioxidant may not cause an adverse effect in human health. Demand for a natural antioxidant is higher than synthetic antioxidant due to safety concern. The antioxidant can shield the food from damage because of oxidation by free radicals and reactive oxygen (Nadeem et al., 2011).

Natural antioxidant and biochemical compounds that occur in some varieties of chilli peppers and have a contribution to maintaining human health have been reviewed (Nadeem, et al., 2011; Embuscado, 2015). Stability of carotenoid in chilli pepper has been reviewed (Arimboor & Natarajan, 2014). Effect processing of bioactive compounds in food have been reviewed (Cilla et al., 2017). Effect of high-pressure processing on colour, flavour, and texture of fruits and vegetables also have been reviewed (Oey et al., 2008). Cooking can also affect the antioxidant content on chilli pepper (Iqbal et al., 2015; Shaimaa et al., 2016), so the right processing method can help to retain the natural antioxidant content of chilli pepper. There is no review has

discussed the effects of processing on the antioxidant content and also physical characteristics of chilli peppers specifically. The aim of this study is to review the effects of processing on the antioxidant content and physical characteristics of chilli peppers.

1.2. General Literature Review

1.2.1. Chilli Peppers

Chilli peppers are a common spice from genus *Capsicum* and family of *Solanaceae* (Wahyuni et al., 2013). Chilli peppers are indigenous to West Indies and South America. Nowadays, chilli peppers are cultivated worldwide in China, India, Africa, Southeast Asia, Japan, and America. There are more than 20 species of chilli peppers, but the major and the most common species of chilli pepper that already recognized are 5 species (Figure 1), they are *Capsicum annuum*, *Capsicum baccatum*, *Capsicum chinense*, *Capsicum frutescens*, and *Capsicum pubescens* (Charles, 2012; Omolo et al., 2014). Lin et al. (2013) said that largest species of *Capsicum* is belong to *Capsicum annuum*, followed by *Capsicum frutescens*, *Capsicum chinense*, and *Capsicum baccatum*.

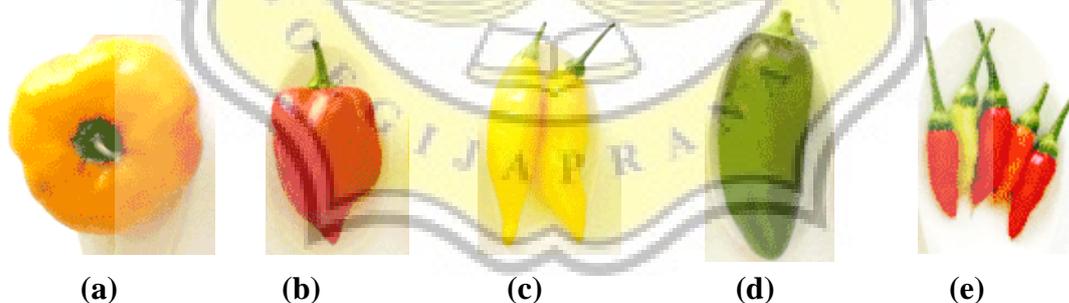


Figure 1. The Most Common *Capsicum* Species. (a) *C. pubescens* (b) *C. chinense*
(b) *C. baccatum* (d) *C. annuum* (e) *C. frutescens*
(Omolo et al., 2014)

According to Dewitt & Bosland (2009), there are 32 species of *capsicum* that had been recognized. The lengths of the leave of *capsicum* species are vary, between 0.25 inch and 5 inches. Some *capsicum* plant has about less than 3 feet of height, while some of the others are taller which about 30 feet are. The shape of *capsicum* fruits are vary such

as elongate, round, conic, oblate, or like a bell. Most varieties of chilli peppers are usually picked at the green stage (after approximately 70 days) and fully-ripened stage (after approximately 130 days).

<i>Capsicum</i> Species		
<i>C. baccatum</i>	<i>C. lanceolatum</i>	<i>C. eximium</i>
<i>C. annum</i>	<i>C. chinense</i>	<i>C. praetermissum</i>
<i>C. friburgense</i>	<i>C. leptopodium</i>	<i>C. flexuosum</i>
<i>C. buforum</i>	<i>C. coccineum</i>	<i>C. pubescens</i>
<i>C. frutescens</i>	<i>C. minutiflorum</i>	<i>C. villosum</i>
<i>C. campylopodium</i>	<i>C. cornutum</i>	<i>C. recurvatum</i>
<i>C. galapoguense</i>	<i>C. mirabile</i>	<i>C. scolnikianum</i>
<i>C. cardenasii</i>	<i>C. dimorphum</i>	<i>C. tovarii</i>
<i>C. hookerianum</i>	<i>C. parvifolium</i>	<i>C. schottianum</i>
<i>C. chaoense</i>	<i>C. dusenii</i>	<i>C. geminifolium</i>
<i>C. hunzikerianum</i>	<i>C. pereirae</i>	

Figure 2. All Species of *Capsicum* (Dewitt & Bosland, 2009)

The term of wild, cultivated, and domesticated that used in chilli peppers are to represent the sequences of human-plant relationships. At the end of this sequence are wild plants that grow outside of the areas inhabited by human. The example of a wild species of chilli pepper is *Capsicum lanceolatum* that only can be found in the virgin rainforest of Guatemala. The next sequence is semi-domesticated cultivars such as *Capsicum annum* var. *glabriusculum*. The last sequence is domesticated plants; one of the examples is bell peppers.

The hotness levels of chilli peppers depend on type and variety of chilli pepper. Capsaicinoid is the main source of pungent flavour of chilli pepper. Chilli pepper contains about 1.5% of a constituent that contributes to pungent flavour. The other component contained in chilli pepper are carotenoid, fat, protein, vitamin, and other volatile compounds (Charles, 2012). Chilli pepper also contains vitamin A, vitamin C, and folate (Kantar et al., 2016). According to Wahyuni et al. (2013), chilli pepper contains biochemical compounds that good for human health such as ascorbic acid, carotenoids, tocopherols, capsaicinoids, and flavonoid. The amounts and kinds of biochemical compounds are vary depending on genotypes, maturation, cultivation systems, and methods of processing.

Dias (2012) also said that fresh chilli pepper contains a lot of vitamin C, vitamin K, carotenoids, and flavonoids. High amount of lycopen which can help to prevent prostate, cervix, and pancreas cancer can be found in red peppers. Beside of phytochemicals compounds, chilli pepper also contains high of fiber.

Hot chilli peppers have about 12 mg/kg total carotenoids in some cultivar, while the other cultivars have bellow the detectable level. Flavonoids contained in chilli peppers are not detectable in some cultivars, while the other cultivars contain for about 800 mg/kg. Red peppers usually have higher nutrition levels than the green one. Chilli pepper also contain B-complex group of vitamins (riboflavin, thiamin, niacin, and pyridoxine). Besides that, chilli peppers are also a good source of minerals (iron, potassium, manganese, and magnesium) (Dias, 2012).

Chilli pepper is often used as a powdered form for industrial food purposes. Quality and the value of chilli peppers depend on the level of pungency and attractive colour. For Western consumers, they prefer to have fruit with the larger size, sweet taste, thick flesh, and vivid colour. Bell pepper or can also be called paprika cultivar are suitable to achieved western consumers preferences. As a spice purpose, hotness, size of fruit, and the thickness of skin are important components. Some examples of chilli pepper cultivars that fit as a spice are cayenne, jatilaba, and laris (Wahyuni et al., 2013).

Wahyuni et al. (2013) divide species of *Capsicum* into three main complexes based on morphological properties, place of origin, karyotype, reproductive behaviour, and biochemical information; they are *Capsicum annum*, *Capsicum baccatum*, and *Capsicum pubescens*. *Capsicum annum*, and *Capsicum baccatum* group has a white coloured flower, while *Capsicum pubescens* has a purple coloured flower. *Capsicum annum* complex consists of *Capsicum frutescens*, *Capsicum annum*, and *Capsicum chinense* that can be intercrossed with each other. *Capsicum baccatum* complex consists of *Capsicum baccatum* var *pendulum*, *Capsicum baccatum* var. *baccatum*, and *Capsicum praetermissum*.



Figure 3. Flower of *Capsicum*. (a) White coloured flower (b) Purple coloured flower (Wahyuni et al., 2013)

1.2.2. Previous Published Review

Lipid oxidation can cause adverse effects such as browning, and development of rancid and off flavour. Lipid oxidation has negative impacts on human health and reduces the nutritional values of food. Not only have an adverse effect on human health, lipid oxidation also plays role in degradation of colour and rancid flavour. The antioxidant can help to prevent lipid oxidation in foods. Antioxidants are very abundant in spices and herbs. Spices like rosemary, sage, oregano, thyme, ginger, turmeric, black pepper, chilli pepper, clove, marjoram, and cumin have high antioxidant activity. Because spices contain a natural antioxidant, it might be a reason that attracts consumers to consume. Consumers prefer to choose a product which contains natural substance because they concern about the harmful effect of synthetic antioxidants (Embuscado, 2015).

Nadeem et al. (2011) also said the appealing reason to consume chilli peppers is that the bioactive compounds and their antioxidant content. Sweet bell pepper (*Capsicum annuum* L.) contains a high amount of ascorbic acid, carotenoid, flavonoid, and polyphenol. Compared with synthetic antioxidants which can be carcinogenic, the natural one is more preferred. Several factors like seasons, cultivars, pre-harvest and post-harvest conditions can lead to affect the biochemical compounds of Sweet bell pepper.

Arimboor & Natarajan (2014) reviewed that carotenoid can prevent and protect against degenerative diseases and can also use as natural food colour. Red peppers (*Capsicum annuum*) are a good source of carotenoid. The carotenoid composition of red peppers are different depends on their varieties and climatic condition of cultivation. Oxidation contributes highest carotenoid loss during processing and storage. Processing and storage may change the nature properties of plant matrices that can result in variation liberation of carotenoids during extraction for analysis that may result in rise of carotenoid contents during processing or storage. The interaction between several components in food matrices might enrich or restrain carotenoids degradation kinetics.

According to Cilla et al. (2017), not only due to the intake level, health benefits from bioactive compounds also depends on their bioavailability. Some combination of thermal treatment and high pressure in the presence of oil can increase the bioavailability of carotenoid. Thermal treatment can also increase the bioavailability of ascorbic acid and polyphenols. High-pressure processing can increase the bioavailability of minerals, tocopherols, and total antioxidant activity. Ultrasound processing can increase the bioavailability of polyphenol and high intensity pulsed electric fields can rise ascorbic acid, carotenoid, and phenolic compounds bioavailability as good as antioxidant capacity. Better knowledge of processing methods and technologies can increase the efficiency to increase bioavailability in foods. The production of food with the improved bioavailability of bioactive compounds can also increase the perception of consumers of the product. Processing variable such as temperature, size of the particles and pressure applied must be carefully controlled so the data can be scaled up into

industrial use. Consensus standard method is needed to evaluate the biological effects of biological compounds with the intention to compare possible data obtained. Nevertheless, general orientation on the use of food processing such as thermal treatment, high-pressure processing, ultrasound, and high intensity pulsed electric field to increase the bioavailability of bioactive compounds doesn't seem to be applicable for every case study.

However, Oey et al. (2008) said that colour, texture, and flavour are also very important characteristics of fruit and vegetables including chilli peppers. They are also the major factors that can be affecting sensory perception and consumer acceptance of foods. High-pressure treatment is an alternative processing that can retain and also minimizing nutritional and sensory quality changes. Compared with other methods of processing, high-pressure processing is a unique technology which is the pressure can improve and inhibit the chemical and biochemical reaction also in both undesired and desired modification of biopolymers such as enzyme activation or inactivation and gel formation.

1.3.Aim of the Study

The aim of this study is to review the effects of processing on the antioxidant content and physical characteristics of chilli peppers.