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Domestic cooking methods affect the nutritional quality of red cabbage

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ABSTRACT

The aim of this work is to investigate the effects of domestic cooking methods, including steaming, microwave heating, boiling and stir-frying on the nutritional quality of red cabbage. Compared with fresh-cut red cabbage, all cooking methods were found to cause significant reduction in anthocyanin and total glucosinolates contents. Moreover, steaming resulted in significantly greater retention of vitamin C and DPPH radical-scavenging activity, while stir-frying and boiling, two popular Chinese cooking methods, led to significant losses of total phenolic, vitamin C, DPPH radical-scavenging activity, and total soluble sugar as well as reducing sugars. Normally, red cabbage consumed fresh in salads could maintain the highest nutrition. However, considering the habits of Asian cuisine, it is recommended to use less water and less cooking time, such as steaming based on our present results, so as to retain the optimum benefits of the health-promoting compounds.

1. Introduction

The consumption of *Brassica* vegetables is related to human health and to reduction of the risk of certain cancers and cardiovascular diseases. *Brassica* vegetables like broccoli (*Brassica oleracea* var. *italica*), radish (*Raphanus sativus* L.), kale (*B. oleracea* L. var. *acephala* DC.) and cabbage (*B. oleracea* L.) are rich in phytochemicals, such as phenolics, vitamins, glucosinolates and anthocyanin, which have a positive impact on human health (Wei, Miao, & Wang, 2011).

Anthocyanins are a class of flavonoids responsible for the attractive bright red, purple, violet, and blue colours of most fruits, vegetables, flowers, leaves, roots and other plant storage organs (Mazza & Miniati, 1993). Anthocyanins as a group of flavonoid compounds fulfill important biological functions in protecting plants against various biotic and abiotic stresses, and in furnishing flowers and fruits with distinct colours to attract insects and animals for pollination and seed dispersal (Harborne & Williams, 2000). Red cabbage (*B. oleracea* L. var. *capitata* f. *rubra* DC.) is distinct in containing high levels of anthocyanins, which has been shown to provide an increased protection in preventing tumour development (Hagiwara et al., 2002).

Before being consumed, most vegetables are commonly cooked. In general, the cooking methods such as steaming, boiling, and microwaving were based on the dietary habit in western society, while stir-frying was used to prepare most homemade dishes in China (Liu & Li, 2000). It is known that cooking induces profound changes in chemical composition, affecting the bioavailability and content of chemo-preventive compounds in vegetables. For example, it has been reported that microwave heating and stir-frying were better to ensure a higher retention of the bioactive components in term of pepper (Chuah et al., 2008). According to Jones, Frisina, Winkler, Imsic, and Tomkins (2010), cooking methods could significantly alter content of glucosinolates and sulforaphane in broccoli florets. *Brassica rapa* vegetables cooked by steaming were better preserved glucosinolates and phenolic compounds than other cooking procedures (conventional boiling and high-pressure cooking) (Francisco, Velasco, Moreno, García-Viguera, & Cartea, 2010).

Red cabbage has been widely consumed as fresh-cut salad, beverage and coleslaw. There have been many literatures on fresh red cabbage, mainly on anthocyanin biosynthesis, glucosinolates or antioxidant-related parameters in red cabbage (Oerlemans, Barrett, Suades, Verkerk, & Dekker, 2006; Volden et al., 2008; Yuan, Chiu, & Li, 2009). However, very little information is available on the effect of cooking on the contents of nutrientional and health-promoting compounds in red cabbage. The purpose of this

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study is to investigate the effects of various cooking procedures on the nutrients and phytochemical compounds in red cabbage.

2. Materials and methods

2.1. Plant materials

Red cabbages (*B. oleracea* L. var. *capitata*. Zaohong) were purchased from local supermarkets (Ningbo, China). About 10 heads of red cabbages were used in this experiment. The red cabbages were cleaned and removed with the outer leaves of the heads, then chopped into homogeneous pieces (3 cm × 3 cm) and randomly selected for each treatment. Each treatment was replicated three times.

2.2. Cooking treatments

Five different cooking methods were tested: fresh-cut, boiling, steaming, microwaving and conventional stir-frying. For boiling, 300 g of homogeneous pieces of red cabbage were immersed in 800 ml of boiling water. The materials were drained off after being boiled for 5 min. For stir-frying, the blend oil (10 ml) was preheated to 130 °C in a wok and materials (300 g) was stir-fried for 5 min. For microwave, 300 g of samples were placed in a plate and 10 ml of water was added to prevent red cabbage from being burned during cooking. A microwave oven at full power (450 W) for 5 min was used for microwaving. Steaming was conducted by suspending 300 g of red cabbage above 200 ml of boiling water for 5 min in a steamer with a lid. In addition, 300 g of red cabbage was collected for fresh-cut samples.

At the end of each cooking treatment, the materials were frozen by liquid nitrogen and kept in polyethylene bags at −20 °C for further analysis.

2.3. Colour measurement

The colour of all samples was evaluated with a Minolta Chromameter (CR 400, Japan). The CIELAB parameters (L^*, a^* and b^*) were determined. L^* was lightness (0–100:0 = black, 100 = white). Values of a^* and b^* ranged from −60 to 60, where a^* was negative for green colour and positive for red colour, and b^* was negative for blue and positive for yellow (McGuire, 1992).

2.4. Total anthocyanin content

Total anthocyanin content was measured by pH-differential spectrophotometry method following the procedure of Rapisarda, Fanella, and Maccarone (2000) with a slight modification. Five grams of frozen sample was extracted with 25 ml of pH 1.0 buffer containing 50 mM KCl and 150 mM HCl, as well as 25 ml of pH 4.5 buffer containing 50 mM sodium acetate and 240 mM HCl. Absorbance was measured at 510 nm and 700 nm with a spectrophotometer, using $A = [(A_{510} - A_{700})\ \text{pH}\ 1.0 - (A_{510} - A_{700})\ \text{pH}\ 4.5]$ with a molar extinction coefficient of cyaniding 3-glucoside of 29600. Results were expressed as milligrams of Cy-3-Glu equivalents per gram of fresh weight.

2.5. Total phenolic content

Total phenolic content was determined by the Folin–Ciocalteu method. One gram of frozen red cabbage sample was extracted with 80% acetone containing 0.2% formic acid, and the mixture was centrifuged at 12,000*g* for 10 min at 4 °C. In brief, an aliquot (20 μl) of sample solution was mixed with 180 μl of distilled water and 1 ml of Folin–Ciocalteu reagent; 7.5% sodium carbonate (800 μl) was added. The reaction mixture was incubated for 1 h at 30 °C. The absorbance was measured at 765 nm with a spectrophotometer. Gallic acid was used as a standard.

2.6. DPPH radical-scavenging activity assay

The DPPH radical-scavenging activity was carried out according to Larrauri, Sánchez-Moreno, and Saura-Calixto (1998). One gram of frozen sample was extracted with 50% ethanol and centrifuged at 12,000*g* for 10 min at 4 °C. An ethanolic solution of DPPH served as control. Antioxidant activity was expressed as percentage inhibition of the DPPH radical and was determined by the following equation:

$$\text{AA}\ (\%) = \frac{\text{Abs}_{\text{control}}\text{Abs}_{\text{sample}}}{\text{Abs}_{\text{control}}} \times 100.$$

2.7. Vitamin C

Vitamin C content was determined according to Kampfenkel, Vanmontagu, and Inze (1995) . One gram of frozen samples were grinded and extracted with 5 ml 5% trichloroacetic acid (TCA), then centrifuged at 10,000*g* for 10 min at 4 °C. A sample of the crude extract (1 ml) was added to 1 ml 5% (v/v) TCA, 1 ml 100% (v/v) ethanol, 0.5 ml 0.4% H_3PO_4, 1 ml 0.5% (v/v) 1,10-phenanthroline hydrate, 0.5 ml 0.03% (v/v) $FeCl_3$, then the mixture incubated at 30 °C for 1 h. The absorbance was read at 534 nm.

2.8. Contents of total soluble sugar and reducing sugar

Total soluble sugar was measured by Roe (1955) with slight modifications. One gram of frozen samples were grinded and extracted with 5 ml of distilled water and incubated at 85 °C for 30 min, then centrifuged at 10,000*g* at 4 °C. The soluble sugar content was determined using anthrone reagent and glucose as standard. Reducing sugars content was determined spectrophotometrically at 540 nm with 3,5-dinitrosalicylic acid.

2.9. Total glucosinolates content

Total glucosinolates content was determined according to Heaney, Spinks, and Fenwick (1988). The method was based on the measurement of enzymically released glucose, which was hydrolysed by the enzyme myrosinase (thioglcose glycohydrolase, EC 3.2.3.1). The content of glucose was determined by the method of phenol–sulfuric acid, to assay the absorbance at 490 nm, and then the amount of glucosinolate can be calculated from the glucose content.

2.10. Statistical analysis

Statistical analysis was performed using the SPSS package programme version 16.0 (SPSS Inc., Chicago, IL). All data were expressed as the mean ± standard error (SE) and analysis by one-way analysis of variance (ANOVA). Differences were considered significant at $p < 0.05$.

3. Results

3.1. Effect of cooking methods on visual changes and surface colour in red cabbage

Changes of external colour of red cabbage were evaluated through L^*, a^* and b^*. The change of colour indexes in samples with different cooking methods is shown in Table 1. Compared with