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Quality of cabbage during long term steaming; phytochemical, texture and colour evaluation

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ABSTRACT

Steaming has been reported to better retain the glucosinolate (GS) content in *Brassica* vegetables than boiling. However, there is little information on the GS content, colour, and texture attributes in *Brassica* vegetables in relation to the duration of steaming. This study investigated the effect of the duration of steaming, which was applied in certain commercial preparation processes, on the GS content, colour, and texture of white cabbage. Results showed that the total accessible content of GSs increases initially during steaming until 10 min followed by a consistent decline up to 180 min. This observed initial increase is mainly due to the content of aliphatic GSs rather than indole GSs, which tend to decrease from the start of steaming. A mathematic model for the observed behaviour of the GSs, taking into account several mechanisms, is proposed and fitted to the data. The intensity of the green colour of the cabbage slightly increased during the first 15 min of steaming followed by a decrease onwards. The hardness showed a continuous decline during the entire steaming duration. The study indicates that steaming up to 10 min could promote the health properties as well as the colour and texture attributes of steamed cabbage.

1. Introduction

Intake of *Brassica* vegetables has been inversely associated with the risk of lung, colorectal, and prostate cancer (Higdon, Delage, Williams, & Dashwood, 2007; Kristal & Lampe, 2002). Several conversion products of glucosinolates (GSs), found almost exclusively in *Brassica* vegetables, are showing biological activities in the human body that are assumed to be responsible for reducing this risk of several cancers (Verhoeven, Verhagen, Goldbohm, van den Brandt, & van Poppel, 1997). In intact plant tissue, GSs are stored in separate compartments from the enzyme myrosinase (thioglucosidase EC 3.2.1.147). However, upon the plant tissue disruption, GSs are highly prone to hydrolytic degradation catalysed by the enzyme (Fahey, Zalcmann, & Talalay, 2001; Mithen, Dekker, Verkerk, Rabot, & Johnson, 2000). Among the breakdown products of the GSs, isothiocyanates have been reported to inhibit phase 1 and to induce phase 2 enzymes that are beneficial with respect to (pro)carcinogen metabolism and excretion (Traka & Mithen, 2009).

GSs are water-soluble compounds that may leach into cooking water during vegetable preparation. For example, boiling of *Brassica* vegetables results in 25%–75% decreases in total GS content (Nugrahedi, Verkerk, Widianarko, & Dekker, 2015). Cooking methods that use less water, such as steaming and microwaving, have shown to reduce GS losses (Rungapamestry, Duncan, Fuller, & Ratcliffe, 2006; Song & Thornalley, 2007; Vallejo, Tomas-Barberan, & Garcia-Viguera, 2002; Verkerk & Dekker, 2004). Several types of processing of *Brassica* vegetables have been studied and many have a pronounced impact on the concentration of GSs and their corresponding isothiocyanates (Verkerk et al., 2009). The observed effects can be explained by multiple mechanisms such as i) myrosinase inactivation, ii) cell lysis and leaching of GSs, breakdown products, and myrosinase in the cooking water, and iii) thermal degradation of GSs (Nugrahedi et al., 2015).

Often, these studies describe various cooking procedures based on the dietary habits and cuisines in the western society. While

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List of abbreviations (variables) used in the equations

$C_{g,w}$ Concentration of GSs in the free water (μmol/g) on/in the cabbage rolls
$C_{g,v}$ Concentration of GSs in the intact part of the vegetable (μmol/g)
$C_{gv,\ measured}$ Concentration of GSs in the intact vegetable tissue that is available for the extraction (μmol/g)
$C_{g,\ measured}$ Concentration of GSs as measured in a sample of the cabbage rolls (in the lysed part as well as in the intact tissue part) (μmol/g)
F_i Fraction of intact cells
$F_{GS\text{-}trapped}$ Fraction of the total vegetable weight
F_{con} Fraction of the condensed steam (free of GSs)
k_l Rate constant of cell lysis (min^{-1})
k_{wg} Rate constant of cell lysis (min^{-1})
$k_{d,w}$ Breakdown rate constant of GSs in the free water pool (min^{-1})
k_T Rate constant of temperature increase due to steaming (min^{-1})
$M\_veg_{inaccessible}$ Mass of the vegetable containing trapped GSs that is not available for the extraction (g)
M_veg_{total} Total mass of the intact vegetable tissue (g)
M_C Mass of condensed steam (g) on/in cabbage rolls
$M_{C,final}$ Final (steady state) mass of condensed steam (g) on/in cabbage roll
M_L Mass of lysed cell content (g)
M_w Mass of free water (g) consisting of the condensate mass and the lysed cell mass
$M_{v,0}$ Initial mass of vegetable (g)
T Absolute temperature (K)
T_{final} Final temperature reached during steaming
t_n Time n; steaming for time of n min
t_0 Time 0; initial time when steaming is started
$|L$ Change of GSs due to leaching
$|D$ Change of GSs due to condensation of steam and drip-flow of condensate
$|C$ Change of GSs due to absorbed condensate mass on/in the cabbage rolls
$|B$ Change of GSs in the condensate due to thermal breakdown

studies on Asian preparation methods of *Brassica* vegetables and the effects on phytochemical content have been underexposed. Probably the processes and underlying mechanisms responsible for GS losses are similar for different cuisines, however the extend of losses can vary based on different characteristics of Asian vegetable preparation methods and the use of different vegetable-based products in the Asian cuisine.

Steaming has been reported to better retain the GS content in *Brassica* vegetables than boiling and blanching (Miglio, Chiavaro, Visconti, Fogliano, & Pellegrini, 2008; Rungapamestry et al., 2006; Volden, Borge, Hansen, Wicklund, & Bengtsson, 2009). However, steaming of *Brassica* vegetables extensively for long times, could result in substantial losses of GSs differently from short steaming processes reported in literature thus far. An example product using long steaming times is cabbage roll, a typical Asian dish made from shortly blanched leaves of white cabbage that are folded and rolled, and subsequently steamed. Steamed cabbage roll is usually served as a kind of dim sum, which includes also e.g.: boiled potato and tofu. The product is produced and sold generally by street- or mobile-vendors (Tan, 2002). During selling, the rolls can be steamed constantly for more than 2 h, depending on the selling rate, on a very low flame level. To our knowledge, there is little information on the behaviour of GSs in *Brassica* vegetables in relation to the long duration of steaming (Song & Thornalley, 2007; Verkerk, Knol, & Dekker, 2010).

In order to understand and simulate the changes of concentration of GSs as affected by processing, previous studies employed kinetic modelling to describe and predict these changes. Leaching and thermal degradation are the main mechanisms affecting GS changes since myrosinase is a thermolabile enzyme and is inactivated early in most thermal processes (Hennig, Verkerk, Bonnema, & Dekker, 2012; Sarvan, Verkerk, & Dekker, 2012; Sarvan, Verkerk, van Boekel, & Dekker, 2014).

Next to these effects of the process on the GS content and subsequent health value, colour and texture are the important sensorial attributes perceived by the consumers to evaluate the quality of both fresh and cooked vegetables (Jackman & Stanley, 1995; Miglio et al., 2008; Nisha, Singhal, & Pandit, 2004). The degree of greenness is an important colour quality attribute of thermally processed green vegetables. The changes of hardness, softness, or firmness can be expressed as important textural quality attributes of vegetables.

The present study aims to investigate the effect of a long duration of steaming on the GS content, colour, and texture of the cabbage roll. In addition the changes of GSs during steaming are also mathematically modelled to gain insight in the important mechanisms involved. In the societal context this study will be beneficial to know the changes of the health-promoting and physical quality attributes of vegetable products and to optimise real preparation methods commonly employed by especially Asian food service establishments.

2. Materials and methods

2.1. Sample preparation

Two batches of raw white cabbages (*Brassica oleracea* L. Capitata) were collected from one local supplier in Semarang, Indonesia on two consecutive days. Six heads of white cabbage were used in each experimental batch. Damaged outer leaf layers of the cabbage heads were removed. Leaf layers of the white cabbage from the surface until about half diameter of the head were taken, washed by running tap water and drained.

2.2. Blanching and steaming

The preparation and processing method of the cabbage rolls was performed in triplicate by mimicking the common practice of the small-scale food service establishments in Semarang, Indonesia. Heat was provided by using a liquefied petroleum gas stove (Rinnai RI-602E, gas consumption = 2.9 kW). Briefly, leaves of white cabbage were blanched in the distilled water at the ratio of 1:6 (kg:L) for 3 min in an open aluminium pan. Then, each leaf was rolled manually resulting in a cabbage roll at the diameter of about 3 cm and the length of about 7 cm. Each roll was made from about 35 g fresh leaves. Each batch of processing took about 5 min for rolling all the cabbage leaves.

Subsequently, all rolls (total weight approximately 2 kg) were steamed in a closed steaming pan containing boiling water for 180 min, comparable with the artisanal procedure often applied in