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Investigation on the relationship between the integrity of food matrix and nutrient extraction yield of broccoli

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ABSTRACT

In this work, experiments to investigate the relationship between the integrity of food matrix and nutrient extraction yield have been conducted. Broccoli was employed as the food material of interest, because of its unique structure and physical properties. Vitamin C was used as the targeted nutrient. The cellular structure disruption conditions were optimized until the maximum nutrient yields were achieved under those conditions. The highest vitamin C yields were achieved when operating time was 5 min for floret, and 10 min for buds and stalks. The highest vitamin C contents were 70.0 g/100 g for florets, 102.6 mg/100 g for buds and 44.2 mg/100 g for stalks respectively. The results indicate that for different parts of a broccoli, presenting different cellular integrity, hardness and porosity, the maximum nutrient extraction yields were different under the same operation conditions. The results of this work have confirmed the determining role of food microstructure in nutrient release during nutrient content measurements or nutrient extraction experiments.

1. Introduction

Research on human health reveals the role of nutrients in preventing diseases and maintaining a balanced health. A diet rich in essential nutrients has a positive effect on human health (Verhoeven, Verhagen, Goldbohm, van Brandt, & van Poppel, 1997; Verkerk et al., 2009). The availability of nutrients is the highest in fresh food products. However, a significant amount of fresh foods are further processed in the food chain to extend shelf life. Drying is a frequently applied operation in food industry. The increased heat load during drying results in a significant degradation of nutrients (Goula & Adamopoulos, 2006; Oliviero, Verkerk, & Dekker, 2012; Zanoni, Peri, Nani, & Lavelli, 1998). Retaining nutrients during drying, is, therefore, a great challenge for food industry.

Dynamic optimization is a powerful method to find optimal drying trajectories to retain the bioactivity (Jin, van der Sman, van Straten, Boom, & van Boxtel, 2014). This approach requires for accurate kinetic models for the degradation kinetics. Mostly, the degradation kinetics is given for well-defined model systems (Mishkin, Saguy, & Karel, 1984; Oliviero et al., 2012). However, most of these model systems ignore the structure changes that occur during sample preparation (for example the destruction of plant cells). Plant tissue is generally compartmentalized (as shown in Fig. 1), i.e. different components are located in different parts of the cellular tissue, such as sugars in vacuoles, protein and fibers in cytoplasm organelles. Vitamin C is present in both the extracellular and intracellular spaces. Glucosinolates are localized in vacuoles, while myrosinase is located in isolated vacuole-like myrosin cells (Kissen, Rossiter, & Bones, 2009). Sample preparation can bring these components in an early phase together with changes of composition as a consequence (Fahey, Zalcmann, & Talalay, 2001). Therefore, it is expected that besides temperature and moisture content effect, structure changes may play an important role in the release, activation and degradation of these components. In our previous work we found for drying of broccolis that the application of degradation kinetics obtained from model systems resulted in overestimation of nutrient degradation (Jin et al., 2014). The deviation arises from the difference in physical state of the samples used in the drying experiments and the samples used for the model systems. The intact tissue protects the components and lowers the degradation rate during drying. Inspired from that work, we start to review the procedure to obtain degradation kinetics. The measurements of degradation kinetics are based on the successful

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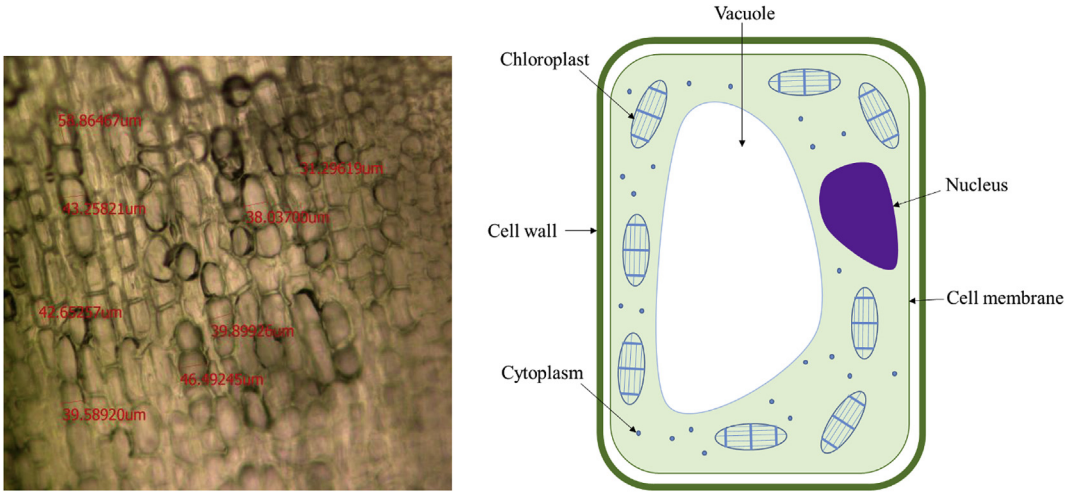

Fig. 1. Typical plant tissue structure and plant cell structure (left: plant tissue structure, the dimensions show the size of one plant cell; right: plant cell structure).

extraction of nutrients from the food matrix. For an efficient extraction process, it is important to make the cell wall permeable and have the cell wall disrupted extensively (Zhao, Baik, Choi, & Kim, 2014). With the reduced particle size and increased surface area, diffusion may play a significant role so that extraction yield can be increased at a given time (Simeonov, Tsibranska, & Minchev, 1999; Zhao, Kwok, & Liang, 2007). For food products with different physical properties, the disruption conditions might be different. Currently, protocols or references are available for measurements of nutrients in most food materials, regardless of the different food status and food physical properties, which can change during food processing (Christiaens et al., 2012; Mølmann et al., 2015). As shown in Table 1 that the homogeneous conditions for frozen broccoli buds, frozen broccoli floret and fresh broccoli florets have little differences though; there are no logical reasons for that. Hence, under these disruption conditions, it cannot be proved that the cellular matrix could be destroyed completely. Consequently, it is possible that some nutrients cannot be released from the food matrix for analysis. This is why inconsistent or conflict results are sometimes reported.

In this work, the relationship between integrity of food matrix and nutrient extractability was examined. Broccoli has been selected as the food material, because of the unique structure and physical properties. Vitamin C was used as the targeted nutrient. With the information of this work, more relevant degradation kinetics during food processing can be constructed.

2. Materials and methods

2.1. Plant materials

For each measurement, fresh broccoli was purchased from the same farmer at Hanlin market at Suzhou city, Jiangsu Province, China. Before each extraction experiment, fresh broccoli was washed and cut into pieces according to the floret, stalks and buds as shown in Fig. 2. The sizes of the floret samples were about 0.02 m in height and 0.02 m in width. The sizes of stalks were about 0.01 m in height and 0.01 m in width. The buds were cut off from the floret. For each measurement, the samples were randomly picked or mixed to reduce the variability from individual specimens and the sample weight was 2.048 ± 0.076 g.

2.2. Homogenization

Each sample was pre-cut in a 50 ml polypropylene centrifugal tube. Afterwards, the sample was homogenized in the presence of TCA (tri-chloro-acetic acid solution, AR, 1 mol/L, pH = 3.0, Sinopharm Chemical Reagent Co., Ltd) at a ratio of 1:7.5 (w/v, weight/volume, g/ml) by a high speed homogenization mixer (Ultra Turrax, T18 + S18N-19G, Ika, Germany) (Jagota & Dani, 1982). The homogenization was done in an ice bath to avoid the nutrient degradation due to increased temperature during processing. The solid residue was rinsed with 10 ml of the cold extraction solution to a final volume of 25 ml. The blender speeds ranged from 500 to 25000 rpm and the blending period ranged from 1 min to 15 min. Then the sample was shaken with a Vortex mixer (Vortex 4, Ika, Germany) at 2000 rpm for 30 s. After that, the homogenate was centrifuged at 5691 g for 20 min at 4 °C. The supernatant was retained and purified with 0.22 μm Millex-syringe filters (Xingya Ltd., Shanghai, China). In the end, the homogenized filtrate was diluted two-fold with TCA solution for vitamin C content analysis.

2.3. Vitamin C measurement and Folin Ciocalteus Phenol reagent dosage optimization

Vitamin C (L-ascorbic acid) was determined by a colorimetric method defined by Jagota and Dani (1982) with modifications. A spectrophotometer (UV-1800, Mapada Instruments, Shanghai, China) was used to measure the absorbance at the wavelength of 930 nm. The amount of Folin-Ciocalteus phenol reagent (BR, 1 mol/

Table 1
Homogeneous conditions for broccoli with different physical states.

Sample	Homogeneous conditions	References
Frozen broccoli buds	24000 rpm, 30s	Rybarczyk-Plonska et al., 2014
Frozen broccoli floret	29000 rpm, 30s	Mølmann et al., 2015
Fresh broccoli floret	First 20 s, low speed and the next 40 s, high speed	Christiaens et al., 2012