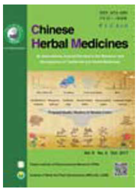

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Original article

Variation of Sweet Chemicals in Different Ripening Stages of Wolfberry Fruits

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ABSTRACT

Objective To evaluate the variation of sweet chemicals (sugars and betaine) in fruits of six species in genus *Lycium* L. i.e. *Lycium truncatum*, *L. cylindricum*, *L. dasystemum*, *L. dasystemum* var. *rubricaulium*, *L. chinense*, and *L. barbarum* harvested at three different ripening stages. **Methods** A simple and effective method based on UPLC-ELSD was developed for the simultaneous determination of two monosaccharides (glucose and fructose), two disaccharides (sucrose and maltose), one sugar alcohol (xylitol), and betaine in wolfberry fruits (goji berries) of genus *Lycium* L. **Results** The six species of wolfberry fruits harvested at the three different ripening stages were evaluated in sugars and betaine contents. Fructose and glucose were the predominant sugars in mature wolfberry fruits. Fructose, glucose, and betaine, as well as total sugar contents, increased continually over the ripening process. *L. truncatum* and *L. dasystemum* had higher contents of sugars and betaine than the other species. **Conclusion** UPLC-ELSD is a simple, reliable and effective method for analysis of the sweet chemicals in wolfberries. Wolfberry fruits at the different ripening stages were significant different in sweetness. *L. truncatum* and *L. dasystemum* could be the potential sources of wolfberry fruit sources.

Key words

betaine; goji berries; sugars; wolfberry fruits

1. Introduction

Berries are traditional and rich sources of bioactive compounds (Seeram et al, 2008). Wolfberry fruits from the Solanaceae family are known botanically as *Lycium barbarum* L., with more familiarly Chinese or western names such as *gouqizi* or goji berries. In addition to being edible, the fruits of *L. barbarum* have been used in traditional Chinese medicine for centuries, and are believed to replenish the *yin* deficiencies of kidney and liver (Wagner et al, 2011). *L. barbarum* is the only wolfberry fruits species in *Chinese Pharmacopoeia* 2015 (Pharmacopoeia Committee of P. R. China, 2015). Modern pharmacological experiments have demonstrated various biological activities of wolfberry fruits, including anti-oxidant,

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immunoregulatory, antitumor, neuroprotective, radioprotective and antidiabetic activities (Amagase et al, 2011; Jin et al, 2013; Tang et al, 2012; Hu et al, 2017).

As an important health food, wolfberry fruits have been intensively studied due to their nutritional elements such as sugars, betaine, carotenoids and vitamins (Olivier, 2010). These compounds are also responsible for the flavor of berries, and their concentration could influence the sensory characteristics of the ripe fruit. *L. barbarum* polysaccharides (LBPs) quantitatively represent the most important group of substances in wolfberry both medicinally and nutritionally (Zhang et al, 2017). Glucose, fructose and the total sugar contents are significantly correlated with the LBPs. Generally, the higher the total sugar content, the better the quality of the fruit. However, if the total sugar content is too high (> 60%), the fruit is easy to be hardened and its commodity quality is decreased (Zhang et al, 2004; Zheng et al, 2008). When ripen, the contents of these compounds may be also one of the key factors for the nutritional quality and organoleptic properties of wolfberry. Betaine, one of the important functional alkaloids in wolfberry fruits, has shown the effect to ameliorate liver damage (Ahn et al, 2014). The taste of wolfberry fruits is also affected by the betaine content; The high betaine levels are associated with the high sweetness of wolfberry fruits (Hye et al, 2014).

Though the wolfberry plants are distributed worldwide, suitable conditions and an age-old cropping history are found in the northwestern parts of China, where the Ningxia Hui Autonomous Region has emerged as a major wolfberry fruit-producing region. The wolfberry has undergone extensive hybridization and suffered from the degeneration of its genetic characteristics. Therefore, it is necessary to find more germplasm resources among varieties with close genetic relationships. There are seven species and three varieties of genus *Lycium* L. in China (Lu and Wang, 2003). Although there are several reports on *L. barbarum* and *L. chinense*, little is known in the sugar and betaine contents of the various species at different ripening stages (Shin et al, 2012; Zhao et al, 2013; 2015). Only a few studies reported on distinction of the fruits of different species in genus *Lycium* L. (Yao et al, 2010).

In this study, the sugars and betaine profiles of wolfberry fruits from six species at different ripening stages were analyzed by UPLC-ELSD. Although several methods have been used to detect these components in wolfberry fruits, they involve complicated operations with time-consuming and poor repeatability. Some methods allow only qualitative evaluation, and others, such as GC, can quantitate different sugar and betaine contents, but require sample derivatization and processing to enable detection (Zhao et al, 2015; Zhang et al, 2007; Zheng et al, 2008). Such manipulations inevitably increase the error in the determinations. Our findings provide basic information for assessing and improving the flavor of the wolfberry fruit, and suggest the marketing potential of other species in genus *Lycium* L. grown in China.

2. Materials and methods

2.1 Chemicals and reagents

All chemicals and reagents were at least of analytical reagent grade. Acetonitrile, methanol and triethylamine were purchased from Merck KGaA (Darmstadt, Germany). Polytetrafluoroethylene (PTFE) membrane filters (0.22 μm) were purchased from Jinteng Technologies (Tianjin, China). All the standards, including xylitol, *D*-(−)-fructose, *D*-(+)-glucose, *D*-(+)-sucrose, maltose and betaine were purchased from Rongcheng Xinde Technology Development Co., Ltd. (China). All the aqueous solutions were prepared using ultra-pure water (18.2 MΩ) obtained from a Milli-Q water purification system (USA).

2.2 Plant materials

Wolfberry fruits of different species were collected in June 2015 from Ningxia Hui Autonomous Region, China, and were identified by Jian-hua Zhao (Ningxia Academy of Agriculture and Forestry Sciences). The voucher species were deposited at the herbarium of National Resource Center for Chinese Materia Medica, China Academy of Chinese Medical Sciences. The samples included *L. truncatum* Y. C Wang (A), *L. cylindricum* Kuang et A. M. Lu (B), *L. dasystemum* Pojark (C), *L. dasystemum* Pojark var. *rubricaulium* A. M. Lu (D), *L. chinense* M. (E) and *L.barbarum* L. (F). The ripening stage included three stages: (I) green period, (II) transitional period and (III) red period (Figure 1). Wolfberry fruits were frozen in liquid nitrogen and then grounded into a fine powder using tissuelyser (Retsch MM 400, USA) for 45 s with a frequency of 30 s^{-1}. The powders were stored at −80 °C until analyzed.

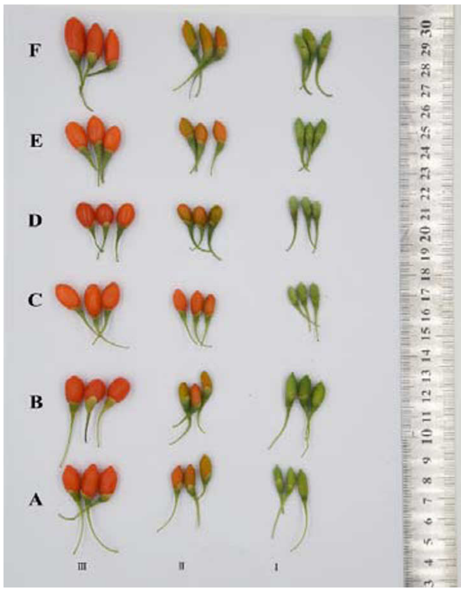

Figure 1 Morphological characteristics of six species of wolfberry fruits in three development stages

A: *L. truncatum*; B: *L. cylindricum*; C: *L. dasystemum*;
D: *L. dasystemum* var. *rubricaulium*; E: *L. chinense*;
F: *L. barbarum*; I: unripe, green; II: ripening, orange; III: ripe, red