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Blueberry anthocyanins in health promotion: A metabolic overview

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ABSTRACT

Diet has gained scientific community attention due to the crucial role in health maintenance, but also in disease treatment, and essential in disease prevention. Several food and food components, particularly phenolic rich foods, have been investigated as they present themselves as putative functional foods. In the past decades, obesity has reached epidemic proportions and consequently, metabolic syndrome (a set of disorders as impaired glucose tolerance, insulin resistance, abdominal obesity, dyslipidemia and high blood pressure, which increase the risk of cardiovascular disease and diabetes) incidence is increasing worldwide at an alarming rate and this phenolic rich foods, specially berries have been investigated to their potential beneficial effect in this disorders.

In the present work the chemistry of blueberries (BB) (fruits of some *Vaccinium* species) was summarised as well as the knowledge about bioavailability and biokinetic of anthocyanins from blueberries with particular emphasis on its implications in metabolic disorders.

Contents

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Abbreviations: acgal, acetylgalactose; acglu, acetylglucose; ACNs, anthocyanins; ara, arabinose; AT, adipose tissue; BB, blueberry/bilberry(ies); BJ, biotransformation of blueberry juice; Cy, cyanidin; C3G, cyanidin-3-glucoside; Dp, delphinidin; D3G, delphinidin-3-glucoside; gal, galactose; glu, glucose; HF, high-fat; IR, insulin resistance; LF, low-fat; Mv, malvidin; M3G, malvidin-3-glucose; NO, nitric oxide; Pg, pelargonidin; P3G, pelargonidin-3-glucoside; Pn, peonidin; PPARγ, peroxisome proliferator-activated receptor gamma; Pt, petunidin; RNS, reactive nitrogen species; ROS, reactive oxygen species; SUG, sugar moiety

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1. Introduction

Diet has a crucial role in health, and consequently in disease treatment, but essential in disease prevention. Thus, knowledge concerning an identification of dietary components involved in disease prevention is a priority in actual science.

In this review we discuss the chemistry of blueberries (BB) (fruits of some *Vaccinium* species) and summarise the knowledge about bioavailability/biokinetic of anthocyanins from blueberries and its role on metabolic disorders.

The consumption of a diet high in fat but rich in polyphenol compounds may minimize the complications of metabolic disorders (DeFuria, Bennett, Strissel, Perfield, 2009; Lila et al., 2011; Meydani & Hasan, 2010; Prior et al., 2008, 2009, 2010; Tsuda, 2008; Tsuda, Horio, Uchida, Aoki, & Osawa, 2003; Valcheva-Kuzmanova et al., 2007). Since the polyphenolic compounds, including ACNs, have strong antioxidant properties, they can confer protection to pancreatic β-cells from glucose-induced oxidative stress (Al-Awwadi et al., 2005; Johansen, Harris, Rychly, & Ergul, 2005; Maritim, Sanders, & Watkins, 2003; Martineau et al., 2006). An excessive adipose tissue (AT) accumulation has metabolic consequences, as adipocyte dysfunction, strongly associated with the development of obesity and diabetes, involving insulin resistance (IR). However, a few studies suggest that AT is an important site of *Vaccinium* species actions to ameliorate obesity complications (DeFuria et al., 2009; Suzuki et al., 2011). ACNs were shown to regulate obesity and insulin sensitivity associated with adipocytokine secretion and PPARγ activation in adipocytes (Tsuda, Horio, Uchida, Aoki, & Osawa, 2003; Tsuda et al., 2004).

The food industry have demonstrated interest in BB, not only because of its known health-promoting properties, but also due to anthocyanin (ACN) unusual colors in acidic conditions (Faria et al., 2005; Faria et al., 2008) as well as some natural ACN derivative pigments (Bakker & Timberlake, 1997; Fulcrand, Benabdeljalil, Rigaud, Cheynier, & Moutounet, 1998; Mateus, Silva, Rivas-Gonzalo, Santos-Buelga, & de Freitas, 2003; Mateus, Silva, Vercauteren, & de Freitas, 2001) that present bluish and orange hues.

2. Blueberry chemistry

The content and profile of phenolic compounds in BB (namely, *Vaccinium angustifolium* (lowbush BB) and *Vaccinium corymbosum* (highbush BB)) has been studied by the scientific community. The phenolic compounds have been reported for their biological activities, such as: (i) anti-oxidant (Borges, Degeneve, Mullen, & Crozier, 2010; Faria et al., 2005; Kahkonen & Heinonen, 2003; Kalt et al., 2001; Mazza, Kay, Cottrell, & Holub, 2002; Prior & Wu, 2006; Tsuda, Horio, Kitoh, & Osawa, 1999; Tsuda, Ohshima, Kawakishi, & Osawa, 1996; Tsuda et al., 1994; Tsuda et al., 2004; Wang et al., 1999); (ii) anti-inflammatory (DeFuria et al., 2009; Karlsen et al., 2010; Schreckinger, Wang, Yousef, Lila, & de Mejia, 2010; Wang et al., 1999); (iii) anti-proliferative (Faria et al., 2010; Li et al., 2009; Pacheco-Palencia, Mertens-Talcott, & Talcott, 2010); (iv) anti-obesity properties (Meydani & Hasan, 2010; Tsuda, Ueno, Kojo, Yoshikawa, & Osawa, 2005; Vuong et al., 2009), and (v) neuroprotective actions (Andres-Lacueva et al., 2005; Barros et al., 2006; Joseph et al., 2003).

Anthocyanins (ACNs) are water-soluble glycosides responsible for the coloration of many fruits, flowers and vegetables, among other, berries (BB, blackberry, chokeberry, elderberry, grape, raspberry, etc.), cherry, strawberry, purple corn, sweet potato and red onions (Borges et al., 2010; Fossen & Andersen, 2003; Kahkonen, Hopia, & Heinonen, 2001; Kalt et al., 2008). The six anthocyanidins commonly found in the edible parts of plants are cyanidin (50%), pelargonidin (12%), peonidin (12%), delphinidin (12%), petunidin (7%), and malvidin (7%) (Kong, Chia, Goh, Chia, & Brouillard, 2003). Their classification is made according to the number and position of hydroxyl and methoxyl groups on the flavan nucleus, i.e., depend on the chemical groups in R1 and R3 (Fig. 1).The most common ACNs found in BB are monoarabinosides, monoglucosides and monogalactosides of cyanidin (Cy), petunidin (Pt), peonidin (Pn), delphinidin (Dp) and malvidin (Mv) though several other phenolic compounds, and their glycosides, have been described (e.g .catechin, epicatechin, myricetin, kaempherol, quercetin, myricetrin and caffeic, *p*-coumaric and ferrulic acids) (Kader, Rovel, Girardin, & Metche, 1996; Riihinen, Jaakola, Kärenlampi, & Hohtola, 2008; Taruscio, Barney, & Exon, 2004). A recent work (Yousef et al., 2013) characterized anthocyanins content of different commercial blueberry cultivars and found that malvidin-3-*O*-galactoside, delphinidin-3-*O*-galactoside, malvidin-3-*O*-arabinoside, cyanidin-3-*O*-arabinoside and delphinidin-3-*O*-arabinoside constituted about 70% of total anthocyanins. Delphinidin and malvidin derivatives are described as the majority of anthocyanins found in blueberries (Rodriguez-Mateos, Cifuentes-Gomez, Tabatabaee, Lecras, & Spencer, 2012; Yousef et al., 2013). Acylated ACNs are also found in blueberries but they account as a small portion of total ACNs. Recently, (Vrhovsek, Masuero, Palmieri, & Mattivi, 2012) has further characterized the flavonol glycosides present in several BB cultivars having found not only a wider array of compounds than those previously described, but also compounds that appeared to be specific of a few of the cultivars (e.g. isorhamnetin-3-rhamnoside was only found in 4 of 15 genotypes tested) or genotypes contemplated in their work. A particular example of a genotype specific compound is quercetin-3-rutinoside, compound only found in one of the two genotypes tested for the *Elliot* cultivar. The differences found between the different papers dedicated to the characterization of the fruit may be a direct consequence of the dif-