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Review

Sorbitol, *Rubus* fruit, and misconception

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ABSTRACT

It is unclear how the misunderstanding that *Rubus* fruits (e.g., blackberries, raspberries) are high in sugar alcohol began, or when it started circulating in the United States. In reality, they contain little sugar alcohol. Numerous research groups have reported zero detectable amounts of sugar alcohol in fully ripe *Rubus* fruit, with the exception of three out of 82 *Rubus* fruit samples (cloudberry 0.01 g/100 g, red raspberry 0.03 g/100 g, and blackberry 4.8 g/100 g*; *highly unusual as 73 other blackberry samples contained no detectable sorbitol). Past findings on simple carbohydrate composition of *Rubus* fruit, other commonly consumed Rosaceae fruit, and additional fruits (24 genera and species) are summarised. We are hopeful that this review will clarify Rosaceae fruit sugar alcohol concentrations and individual sugar composition; examples of non-Rosaceae fruit and prepared foods containing sugar alcohol are included for comparison. A brief summary of sugar alcohol and health will also be presented.

Contents

1. Introduction

It is well established that *Rubus* fruit contain a rich array of phenolics, as summarised in Lee, Dossett, and Finn (2012), and they have long been popular due to their unique flavours (Dossett, Lee, & Finn, 2008). *Rubus* fruits are also a good source of dietary fibre, vitamins, and minerals (Kaume, Howard, & Devareddy, 2012; Lee et al., 2012; Rao & Snyder, 2010), however there is a common misconception among nutritionists, dietitians, and consumers that the sugar alcohol (also known as carbohydrate, simple polyol, and mostly acyclic polyols) content of blackberries and red raspberries (both in the genus *Rubus*) is high (personal observation). It is unclear how or when this misunderstanding began to circulate, but the confusion could stem from *Rubus* belonging to the plant family Rosaceae, which includes plums and cherries (see section on subfamily Amygdaloidae sugar alcohols section below). Considering current understanding of healthy diets, it is all the more unfortunate that misinformation can cause unnecessary consumer avoidance of fruits or vegetables (Kaume et al., 2012; Lee et al., 2012; Rao & Snyder 2010).

Fruit sugar identifications have aided plant taxonomy classification within Rosaceae (Bieleski, 1982; Moing, 2000; Wallaart, 1980), and their profiles (i.e., glucose:fructose ratio, presence or absence of specific sugar) can reveal adulteration in fruit juices and concentrates (Spanos & Wrolstad, 1987; Wrolstad, Cornwell, Culbertson, & Reyes, 1981, chap. 7; Wrolstad & Shallenberger, 1981). Despite improvements in technology, modern authenticity and assurance

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testing is still dependent on fruit sugar profiles (Nuncio-Jauregui, Calin-Sanchez, Hernandez, & Carbonell-Barrachina, 2014; Thavarajah & Low, 2006; Turkmen & Eksi, 2011). An example of Rosaceae family adulteration could be red raspberry (*Rubus idaeus* L.) products using less costly apple (*Malus domestica* L.) or pear (*Pyrus* L.) concentrates, desired sweetness would be attained while still able to assert 'no added sugar' on the label. Simple carbohydrate profiles can also be used in food standard of identity, quality assurance, and quality control for canned fruits, canned fruit juices, fruit jellies, and fruit preserves (21CFR145). Although it would be a challenge to rely on sugar profiles alone to detect ingredient adulteration, but when combined with other measurements like phenolics, free amino acids, organic acids (nonvolatile acids), or DNA testing, food agencies are able to readily identify suspect fruit products (Durst, Wrolstad, & Krueger, 1995; Lee, 2014; Nuncio-Jauregui et al., 2014; Scott & Knight, 2009; Thavarajah & Low, 2006; Van Gorsel, Li, Kerbel, Smits, & Kader, 1992).

It is unclear how nutrition professionals and consumers originally became misinformed regarding sugar alcohol levels in *Rubus* fruit. The goal of this review article is to clarify and summarise findings about the sugars found in *Rubus* fruit, and the sugars within other commonly consumed fruit from the family Rosaceae. Health benefits and risks of sugar alcohol will be briefly summarised in a later section.

2. Occurrence of sugar alcohol

Though the focus of this review is limited to the family Rosaceae (references that provided relevant values are in Tables 1–3), sugar alcohol can be found in a multitude of foods. The occurrence, distribution, metabolism, and role of sugar alcohol within plants have been well summarised (Bieleski, 1982; Loescher, 1987; Merchant & Richter, 2011; Moing, 2000; Williamson, Jennings, Guo, Pharr, & Ehrenshaft, 2002), while additional work to clarify its functions is ongoing (Williamson et al., 2002).

Sugar alcohols are present in many food crops: from apples, to seaweeds, and to mushrooms (Bieleski, 1982; Haas & Hill, 1932; Mizuno & Zhuang, 1995; Zhou et al., 2012; references listed in Tables 1–3). Known findings include apple, peach, apricot, nectarine, pear, plum (red, prune, and yellow), blackberry, red raspberry, cloudberry, red and black currant, elderberry, strawberry, bilberry, sweet cherry, sour cherry, loquat, pomegranate, whortleberry, cranberry, sea buckthorn, common hawthorn, rowan berry, narrow firethorn, mushrooms, celery, avocado, plantain, banana, grapefruit, pineapple, kiwifruit, papaya, coffee, olive, and algae. The plant kingdom is widely represented (families of Actinidiaceae, Adoxaceae, Apiaceae, Bromeliaceae, Caricaceae, Elaeagnaceae, Ericaceae, Grossulariaceae, Lauraceae, Lythraceae, Musaceae, Oleaceae, Plantaginaceae, Rhodomelaceae, Rosaceae, Rubiaceae, and Rutaceae), along with the fungi kingdom (families of Auriculariaceae, Boletaceae, Cantharellaceae, Hericiaceae, Marasmiaceae, Meripilaceae, Pleurotaceae, and Tremellaceae) (Cantin, Gogorcena, & Moreno, 2009; Colaric, Veberic, Stampar, & Hudina, 2005; Haas & Hill, 1932; Ledbetter, Peterson, & Jenner, 2006; Liu, Robinson, Madore, Witney, & Arpaia, 1999; Makinen & Soderling, 1980; Megias-Perez, Gamboa-Santos, Soria, Villamiel, & Montilla, 2014; Moing, 2000; Mizuno & Zhuang, 1995; Muir et al., 2009; Nadwodnik & Lohaus, 2008; Richmond, Brandao, Gray, Markakis, & Stine, 1981; Serrano et al., 2003; Strain, 1937; Turkmen & Eksi, 2011; Wodner, Lavee, & Epstein, 1988; Wu, Quilot, Kervella, Genard, & Li, 2003; Zhou et al., 2012; and additional references listed in Tables 1–3). Additionally, the sugar alcohol concentration within the edible parts of a plant or fungus fluctuate due to many variables, including fraction (leaf, stem, fruit, etc.), ripeness, species, genus, cultivar, genotype, environment, cultivation, processing, and storage conditions (Cantin et al., 2009; Durst et al., 1995; Fuzfai, Katona, Kovacs, & Molnar-Perl, 2004; Hecke et al., 2006; Liu et al., 1999; Makinen & Soderling, 1980; Merchant & Richter, 2011; Moing, 2000; Wallaart, 1980; Wodner et al., 1988).

3. Simple carbohydrates found in *Rubus* and other Rosaceae fruit

Red raspberry fruit, as an example of *Rubus* fruit, has been reported to contain glucose, fructose, sucrose, sorbitol, mannitol, and *myo*-inositol (Durst et al., 1995; Makinen & Soderling, 1980; Megias-Perez et al., 2014; Muir et al., 2009; Sanz, Villamiel, & Martinez-Castro, 2004; Spanos & Wrolstad, 1987; Washuttl, Riederer, & Bancher, 1973). Although, some references have not reported every individual sugar listed above and discrepancies might have arisen from variation in sample, preparation, column, detector, or method conditions (Ellefson, 2005; Fuzfai et al., 2004; Muir et al., 2009). Table 1 summarises total sugars and total sugar alcohols in fresh weight (fw) fruit from 22 genera and species, by dry weight (dw) in Table 2, and by their products in Table 3.

Data from the Rosaceae family show subfamily Amygdaloidae (tree fruits; drupes and pomes fruiting body) contained higher levels of sugar alcohols than subfamily Rosoideae (canefruit, shrubs, etc.; aggregated fruit body). Amygdaloidae fruit (apple, plum, apricot, etc.; see Tables 1–3) sugar alcohol levels ranged from none detected to 6.8 g/100 g fw (sweet cherry), while the range in Rosoideae fruit (strawberry, blackberry, raspberry, etc.; see Tables 1–3) was from undetected (most Rosoideae fruit listed in Table 1) to 0.06 g/100 g fw (strawberry; excluding the Muir et al. 2009 atypical result of 4.8 g/100 g fw). Sugar alcohol concentration and composition changed when reported in dry weight (Table 2). Dehydration (i.e., freeze drying, oven drying, or air drying) likely alters the detectable sugar proportions by naturally concentrating fruit metabolites and decreasing the fleshy part to seed ratio. For example, mannitol, xylitol, and *myo*-inositol (Megias-Perez et al., 2014; Washuttl et al., 1973) were found in dehydrated red raspberries but not fresh red raspberries (Makinen & Soderling, 1980).

Products (Table 3) of Amygdaloidae fruit (not detected to 18 g/100 mL or 100 g) had higher sugar alcohol than those of Rosoidae (not detected to 0.21 g/100 mL or 100 g), which is consistent with the trends these subfamilies had in their respective starting materials (Table 1). Dried prune plums (up to 18 g/100 g) and prune plum juices (up to 7 g/100 g) contained the highest amount of sugar alcohols (Stacewicz-Sapuntzakis, 2013; Stacewicz-Sapuntzakis, Bowen, Hussain, Damayanti-Wood, & Farnsworth, 2001). Conversely, a serving of strawberries (140 g fw), using the highest sugar alcohol level reported (0.06 g/100 g fw), would contain only 0.08 g of sugar alcohol. Even with an uncharacteristically high blackberry value (Muir et al., 2009), a serving (140 g fw) might contain 6.7 g of sugar alcohol. But, at the highest blackberry juice sorbitol reported (Fan-Chiang & Wrolstad, 2010), 0.21 g/100 mL, one serving (8 oz) would contain only 0.50 g of sugar alcohol. Again, most Rosoideae fruit products contained well below 0.21 g of sugar alcohols/100 mL or 100 g. Most of the *Rubus* fruit (see Table 2; except the Muir et al. 2009 sample) contained less sugar alcohol than gluten free Muesli (0.89 g/100 g fw), chocolate chip biscuits (0.08 g/100 g fw), sweet plain biscuits (0.21 g/100 g fw), or pretzels (0.13 g/100 g fw) (Biesiekierski et al., 2011). Additional sugar alcohol values for fruits, vegetables, grains, etc. can be found in Biesiekierski et al. (2011), Muir et al. (2009), Washuttl et al. (1973), and Yao et al. (2014).

Processing schemes can elevate sugar alcohol concentrations in finished products. Any food production using a commercial pectinase might be introducing sorbitol into their final products, as shown in Durst et al. (1995), where they reported from none detected to 55 g of sorbitol/100 g ($n = 33$) in available pectinase