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Comparative analysis of maple syrup to other natural sweeteners and evaluation of their metabolic responses in healthy rats

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ABSTRACT

Maple syrup is a natural source of carbohydrates but its metabolic impact remains poorly studied. We undertook to systematically compare the chemical composition of maple syrup with that of other natural sweeteners, and assess their metabolic responses in healthy rats. As compared to other sweeteners, maple syrup is particularly rich in polyphenolic lignans and in the phytohormone abscisic acid and its derivatives. Metabolic studies in rats showed that maple syrup produced significantly lower peak and global responses of glucose, insulin, amylin and gastric inhibitory polypeptide (GIP) as compared to brown rice syrup, corn syrup and pure dextrose. The metabolic effects of agave syrup and molasses were similar to that of maple syrup, while honey caused higher peak responses for insulin, amylin and GIP. Both the composition of maple syrup and the metabolic responses to its ingestion in rats indicate that it represents a healthy natural alternative to refined sugar.

1. Introduction

Simple and complex carbohydrates are an essential part of any balance diet. Nevertheless, the WHO suggests that added sugars should not represent more than 10% of the caloric intake, a recommendation not necessarily followed in the western diet (Sibbald, 2003). Added sugar is generally consumed as a transformed sugar, composed almost exclusively of carbohydrates, lacking vitamins, minerals, polyphenols and other biomolecules that could provide beneficial health effects. On the other hand, some natural sweeteners have been proposed to provide health benefits owing to their rich polyphenol content and their antioxidant properties measured *in vitro* (Biesaga & Pyrzynska, 2013; Caderby et al., 2013; Erejuwa, Sulaiman, & Wahab, 2012). Therefore, replacement of refined sugars by an unprocessed

Abbreviations: ABA, abscisic acid; PA, phaseic acid; DPA, dihydrophaseic acid; 7-OH-ABA, 7-hydroxy-abscisic acid; ABA-GE, abscisic acid glucose ester; trans-ABA, trans abscisic acid; Neo-PA, neo-phaseic acid; HbA1c, higher glycated haemoglobin 1c; CVD, cardiovascular disease; GLP-1, glucagon-like peptide-1; GIP, gastric inhibitory peptide

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natural sweetener could be a judicious alternative to encourage the intake of active functional biomolecules, representing a healthier food choice for the consumer, and for the industry eager to respond to the new consumer requests for improved food products. In line with this, natural sweeteners have been proposed to impact positively on various disorders. As an example, honey has been proposed as a complementary agent in the management of diabetes (Erejuwa et al., 2012).

In recent years, maple syrup has sparked much interest as a healthy natural sweetener. Maple syrup is produced by boiling the sap of maple trees (*Acer* sp.), generating a light brown to dark syrup titrating 66% sugar. This process concentrates the carbohydrates (mainly sucrose) as well as other compounds that are present within the sap (e.g. minerals, organic acids, vitamins, phenolic compounds and phytohormones) (Kermasha, Goetghebeur, & Dumont, 1995; Stuckel & Low, 1996; Waseem, Phipps, Carbonneau, & Simmonds, 1991). Interestingly, some of these components have been proposed to exert beneficial health properties, particularly on glucose homeostasis. Indeed, some of the phenolic compounds isolated from maple syrup were shown to have α-glucosidase inhibitory activity, suggesting that these molecules could limit glucose absorption by the intestine in response to the sweetener's ingestion (Li & Seeram, 2010; Wan et al., 2012). Furthermore, maple sap contains abscisic acid (ABA), a phytohormone regulating plant growth, development, dormancy and stress responses (Bertrand, Robitaille, Castonguay, Nadeau, & Boutin, 1997; Bertrand, Robitaille, Nadeau, & Boutin, 1994; Li & Seeram, 2011a). Interestingly, the promising potential of abscisic acid (ABA) as an anti-diabetic molecule has been proposed (Bruzzone et al., 2008; Guri, Hontecillas, & Bassaganya-Riera, 2010; Guri et al., 2008; Guri, Hontecillas, Si, Liu, & Bassaganya-Riera, 2007). Indeed, this phytohormone shares structural similarities with thiazolidinediones, a class of antidiabetic drugs, and recent studies have shown that ABA can exert protective effects in animal models of type 2 diabetes (Guri et al., 2007, 2010).

In order to make informed food choices, it is important to look at the impact of the different sweeteners in term of circulating glucose and insulin responses. Indeed, low glycaemic index diets have been shown to improve glycaemic control and reduce serum lipids in diabetic and hyperlipidaemic subjects (Jenkins et al., 1987). Furthermore, a recent meta-analysis revealed that the risk of cardiovascular events increases with higher glycated haemoglobin 1c (HbA1c) levels. Since HbA1c primarily captures postprandial spikes and persistently elevated blood glucose concentration, this suggests a link between poorly controlled post-meal glycaemic responses and the risk for cardiovascular disease (CVD) (Santos-Oliveira et al., 2011). Such clinical evidences have led different diabetes associations to recommend the consumption of low glycaemic index food in order to have a better control on post-prandial glycaemia and to reduce CVD risk (Katsilambros, Liatis, & Makrilakis, 2006). In the insulin-resistant, pre-diabetic state, higher pancreatic insulin secretion is pathognomonic to insulin resistance in altered metabolic states. Hyperinsulinaemia compensates for the reduced ability of normal concentrations of insulin to control blood glucose but this is at the cost of contributing to obesity-related complications such as hepatic steatosis and CVD, and eventually leads to pancreatic beta-cell dysfunction and type 2 diabetes.

The metabolic responses induced by food ingestion are not limited to glucose and insulin. In recent years, a plethora of hormones secreted in response to food consumption has been demonstrated to be important for adequate glucose control. Upon food ingestion, the gastrointestinal tract releases several peptidic hormones that contribute to insulin secretion and nutrient metabolism through endocrine and paracrine mechanisms in several tissues. The peptidic hormones glucagon-like peptide-1 (GLP-1) and gastric inhibitory peptide (GIP) are called incretins. Their secretagogue action is best appreciated after a meal or following an oral glucose tolerance test, which induce greater insulin secretion compared to the response exerted by the same amount of glucose is intravenously administered. This phenomenon, known as the incretin effect, accounts for 50–70% of the insulin response after a meal or oral glucose bolus (Nauck et al., 2004). Furthermore, other hormones have been shown to be an integral part of the metabolic response to foods. These hormones include two pancreatic peptides: amylin, which is secreted along with insulin in a ratio of 1:100 (Kahn et al., 1990; Lutz, 2012), and glucagon, which ensures the maintenance of basal blood glucose during fasting periods. Other tissues also contribute to the metabolic response by secreting "food intake-related hormones". These include ghrelin, a gastric hormone known to stimulate food intake (Inui, 2001), as well as leptin, a satiety-inducing hormone that is secreted mainly by adipose tissue (Loftus, 1999).

In the present study, we have compared the amounts and types of carbohydrates, polyphenols, and ABA-derived molecules in maple syrup and other natural sweeteners. We found that maple syrup is a rich source of ABA-related molecules and polyphenols, and produces low glycaemic and insulinaemic responses *in vivo*, and thus represents a natural sweetener alternative to refined sugar.

2. Material and methods

2.1. *Sweeteners*

The sweeteners used in the present study are all available commercially. The sweeteners were: pure maple syrup (gift from the Québec Maple Producers), molasses (GRANDMA; Saint-John, NB, Canada), organic brown rice syrup (SWEET DREAMS; Richvale, CA, USA), organic blue agave syrup (WHOLESOME SWEETENERS; Sugar Land, TX, USA), golden corn syrup (CROWN; Memphis, TN, USA) and pure natural honey (McCORMICK; London, ON, Canada).

2.2. *Determination of the carbohydrate, polyphenol and ABA contents of sweeteners*

2.2.1. *Carbohydrate analysis of sweeteners*

The carbohydrate composition of the sweeteners was determined using a HPLC Waters system (Millipore Corp., Milford, MA, USA) coupled with a refractive index detector (model 2142, LKB, Bromma). Samples were diluted and filtered through a 0.45 μm Millipore filter prior to injection into the HPLC. The column used was a Waters Sugar-Pack-I, made out of sulfonated cross-linked styrene-divinylbenzene copolymer in the