

A review of sugar consumption and mood fluctuations

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Abstract

Consuming sugar has been connected to mood swings, which can have both short-term and long-term impacts on mental health. An early sensation of euphoria or enhanced energy may result from brief rises in glucose levels following the consumption of sugary meals. But this is frequently followed by a sharp drop in blood sugar, which causes mood swings, exhaustion, and irritation. For some people, these swings can make their anxiety and depression symptoms worse. Long-term mood disorders have also been linked to chronic excessive sugar intake, maybe as a result of its effects on inflammation, insulin regulation, and brain chemistry. In order to manage mental health and encourage healthy eating habits, it is essential to comprehend the connection involving sugar and mood swings.

Keywords: Blood sugar levels, mood swings, insulin management, brain chemistry, emotional health, energy fluctuations.

Introduction

Over the last decades, consumption of sugar-sweetened soft drinks has increased dramatically. In the US alone, consumption of such drinks has increased by 135% from the 1970s to the early 2000s (Nielsen and Popkin, 2004). Similar findings have been reported in countries all over the world, including Germany, Spain and the United Kingdom (for a review, see Malik et al., 2010), with annual sales of energy drinks alone surpassing four billion EUR across Europe (490 million liters consumed; see Zucconi et al., 2013).

Currently, soft drinks are a major contributor to daily energy intake, accounting for more than 7% of energy consumption and representing the largest single source of calories in people's diets (Block, 2004). The widespread appeal of sugar-sweetened and energy drinks is associated with the marketing of these products as a way of combating fatigue, increasing energy and promoting a euphoric feeling. As the main ingredient in such drinks is sugar, research has focused on understanding how sugar-sweetened drinks, and carbohydrates (CHOs) in general, might promote cognitive facilitation and emotional wellbeing (for reviews, see Benton, 2002; Benton and Donohoe, 1999a; Gibson and Green, 2002; Smith et al., 2011; SünramLea and Owen, 2017).

Several influential studies have suggested that CHO ingestion might have mood-boosting properties. It has been observed that, compared with healthy populations, individuals suffering from affective conditions (e.g., seasonal affective disorder and depression) tend to 'self-medicate' by increasing their daily consumption of CHO-rich meals and beverages (Wurtman and Wurtman, 1989, 1995, 2018).

On the other hand, recent studies have suggested that, on top of the metabolic health concerns associated with high levels of sugar consumption (e.g., Malik et al., 2006; Vartanian et al., 2007), high long-term consumption of CHOs has adverse effects on psychological wellbeing, even leading to higher rates of depression (Knüppel et al., 2017; Westover and Marangell, 2002). This ongoing debate has renewed the interest of researchers, media and the public in the relationship between sugar and mental wellbeing. As the trend for high consumption of sugary drinks shows no signs of abating, understanding the appeal of these products and the mental and physical health consequences of their consumption is of high priority.

Despite researchers not having reached a consensus regarding the exact effects of sugar on mood, it seems that the public strongly believes in the idea that sugar improves mood ('Why is sugar so addictive?', 2013) and increases activity levels (especially in children; Furnham, 2018). Although it is difficult to pinpoint the exact pathways that have made the 'sugar rush'

notion so widely influential in popular culture, the origins of this notion can be traced back to studies suggesting that consumption of CHOs may increase hyperactivity in children (Flora and Polenick, 2013; Rojas and Chan, 2005; Wolraich et al., 1994, 1995; Yu et al., 2016). Whereas it is generally accepted that children's 'sugar rush' is a myth (for a meta-analysis, see Wolraich et al., 1995), there is less agreement about the effect of sugar on mood. The purpose of the present review is to address the assertion that consumption of CHOs can affect mood. We begin by reviewing the theory behind the supposed neurobiological substrates of CHO-mood interactions, as well as the criticism that this framework has received over the years. We then present the current state of the field by discussing studies supporting and rejecting the claim that CHOs can improve mood, as well as how methodological differences among these studies could help explain these conflicting findings.

Carbohydrates and mood:

Mechanisms and evidence The rationale behind the assertion that CHOs improve mood has a strong physiological basis. Consumption of pure CHOs is associated with an increase in neurotransmitter synthesis and uptake in the brain. Specifically, the availability of neurotransmitters such as glutamate, acetylcholine and gamma-aminobutyric acid appears to be modulated by exogenous glucose supply (for a review, see Messier, 2004). For example, in mice, even small doses of glucose have been found to increase acetylcholine synthesis and release in the hippocampus (Durkin et al., 1992) and facilitate cognitive performance (Kopf et al., 2001). Additionally, the effects of glucose on gamma-aminobutyric acid release are also accompanied by alterations in dopaminergic activity (Levin, 2000), further strengthening the assertion that glucose is an important precursor to neurotransmitter synthesis (also see Yeghiayan et al., 2004). The serotonergic system in particular is susceptible to CHO manipulations, and it has been suggested that the supposed effects on mood are related to fluctuations in serotonin availability following CHO ingestion (for reviews, see Gibson, 2007; Markus, 2008; Spring et al., 1987).

Serotonin and mood:

It is well-established that serotonin and mood are intrinsically related, with the serotonergic system being implicated in the etiology of a number of mood disorders, including depression, mania, seasonal affective disorders, anxiety and aggression (for reviews, see Chaouloff et al., 1999; Jenkins et al., 2016; Marek et al., 2003; Sandyk, 1992). Studies manipulating levels of tryptophan (a precursor to serotonin) using tryptophan depletion protocols have found low mood, increased irritability and aggression in human volunteers. However, restoring tryptophan levels has been shown to have antidepressant qualities and can reduce levels of aggression in human volunteers (for reviews, see Jenkins et al., 2016; Young and Leyton, 2002). It has been observed that both CHO administration and insulin injections in rats are followed by a marked increase in tryptophan (large neutral amino acid; LNAA) in the plasma as well as higher levels of serotonin and tryptophan concentrations in the brain (Fernstrom and Wurtman, 1971, 1972).

Similar findings have been reported in humans, with CHO consumption leading to higher tryptophan availability in the periphery (Fernstrom, 1990; Markus, 2007; Markus et al., 1998, 1999; Rosenthal et al., 1989), accompanied by increased levels of brain tryptophan and a surge in serotonin synthesis (Carpenter et al., 1998; Markus, 2008; Nishizawa et al., 1997; Williams et al., 1999). Whereas protein consumption has been found to decrease tryptophan availability (Fernstrom et al., 2013), ingestion of pure CHOs leads to a higher tryptophan:LNAA ratio, despite CHOs being devoid of tryptophan (Fernstrom and Wurtman, 1971; Markus, 2007). This is because insulin secretion following a meal high in CHOs results in all LNAAs except for tryptophan to be taken up by tissue (e.g., muscle) and, consequently, tryptophan levels remain high compared to other LNAAs (Cangiano et al., 1983; for a review, see Bellisle et al., 1998). As tryptophan competes with other amino acids to cross the blood-brain barrier, such higher tryptophan:LNAA ratio increases tryptophan influx in the brain, resulting in higher brain tryptophan concentrations and increased serotonin synthesis

(for reviews, see Gibson, 2007; Markus, 2008; Spring et al., 1987; Wurtman and Wurtman, 2018).

The supposed effects of CHO on mood are posited to be related to the increase in serotonergic activity following CHO ingestion. It should be noted that this serotonin surge (or, at the very least, the increase in tryptophan availability in the brain) is observed only when CHOs are consumed alone and not when ingested in combination with other macronutrients. Specifically, CHO meals and beverages containing as little as 5% protein do not increase tryptophan concentrations (Yokogoshi and Wurtman, 1986; for a review, see Benton and Donohoe, 1999b).

Some studies have failed to observe increases in tryptophan and serotonin availability following CHO ingestion (Teff et al., 1989), suggesting that the CHO-tryptophan relationship could be mediated by other factors, including CHO dose or the presence of protein in the stomach from a previous meal, which can attenuate the effect. Although the real-life applicability of the CHO-serotonin-mood relationship has been challenged because meals typically contain enough protein to suppress a CHO-related increase in tryptophan (Benton, 2002; Benton and Donohoe, 1999a; Benton and Nabb, 2003; Spring et al., 1987), the majority of commercially available soft drinks do not contain any macronutrients other than CHOs. Considering the global increase in the consumption of CHO-rich soft drinks, investigating the extent to which sugar affects mood is an important step in understanding and managing the appeal of these products.

Over the years, evidence has been accumulating in support of the premise that CHOs can improve mood. For instance, Benton and Owens (1993) found that an increase in blood glucose levels after the consumption of 50 g of CHOs is associated with decreased levels of tension (also see Smit et al., 2004). CHO administration has also been related to increased ratings of activation and arousal (Backhouse et al., 2007), higher alertness following a 2-h fast (Owen et al., 2012), higher levels of subjective positive affect (Backhouse et al., 2005; Peacock et al., 2012), lower levels of confusion (Lieberman et al., 2002) and tension (Lieberman et al., 2002;

Markus, 2007), higher levels of clear-headedness (Smit et al., 2004), and less fatigue (Markus, 2007; Reay et al., 2006). Furthermore, CHO ingestion has been shown to be related to increased calmness (Spring et al., 1982), particularly following a long period of fasting (i.e., overnight fast; Owen et al., 2012).

The literature on CHO effects on cognition suggests that CHOs can improve cognitive functioning, particularly under circumstances where participants are asked to perform cognitively demanding rather than easy tasks (Mantantzis et al., 2017; Scholey et al., 2009; Sünram-Lea et al., 2002). In a similar manner, studies have found the protective effects of CHOs on mood to be more robust when participants perform demanding physical and cognitive tasks. In fact, whereas participants in control groups experience higher levels of tiredness after performing a cognitively demanding task, consumption of CHOs seems to protect subjective ratings of energy against a potential drop-off after high cognitive exertion (Benton and Owens, 1993; Owens et al., 1997). Additionally, exogenous energy supply in the form of CHOs has been shown to increase vigor and reduce fatigue under conditions of increased physical stress (Ali et al., 2017; Lieberman et al., 2002; Markus, 2007; Welsh et al., 2002) and cognitive demands (Owens et al., 1997; Smit et al., 2004).

Therefore, it has been hypothesized that, similar to cognition, mood improvement following CHO administration is stronger when participants have to perform demanding cognitive or physical tasks (for a review, see Benton, 2002). Furthermore, consumption of CHO-rich foods (i.e., meals with a high CHO-to-other-macronutrients ratio) has been found to have a protective effect against increases in subjective ratings of depression and performance-related declines in vigor, specifically in individuals prone to stress (Markus et al., 1999; Markus et al., 1998).

- Meals high in CHOs can also decrease levels of fatigue compared with meals high in protein (Lloyd et al., 1996). Additionally, whereas consumption of lowCHO diets over long periods increases depression, tension, anger and fatigue (Deijen et al., 1989)

- CHO-rich diets can lead to lower hypothalamic-anterior pituitary-adrenocortical axis stress response (Anderson et al., 1987; Blass, 1987; Drewnowski et al., 1992)
- CHOs might have a protective effect against stress and depression (Dallman et al., 2003; Wurtman and Wurtman, 1989, 1995).
- Similarly, it has been found that self-reported levels of daily CHO intake are negatively associated with depression ratings (de Castro, 1987; for a review, see Soh et al., 2009).
- Researchers have hypothesized that the relationship between CHO-rich meals, serotonin and mood is so potent that CHO meals are consumed as ‘comfort foods’ by individuals suffering from mood or affective disorders in an effort to improve their mood (for a review, see Wurtman and Wurtman, 2018).

Studies have used varied fasting intervals prior to CHO administration, ranging from no fasting (Reid and Hammersley, 1998) to 2-h (Giles et al., 2012) and overnight fasting restrictions imposed (e.g., 12 h; Owen et al., 2013; Scholey et al., 2014). However, the moderating effect of fasting duration on CHO effects is not yet clear. In fact, one of the few studies investigating how fasting intervals affect CHO effects on mood has found calmness and alertness to be differentially affected by CHOs under different fasting restrictions (Owen et al., 2012). Specifically, whereas the CHO group’s alertness ratings increased following a 2-h fast, higher levels of calmness were found only for the CHO groups that were required to fast overnight. Although a 2-h fast is usually the minimum requirement to observe CHO facilitation effects (for a meta-analysis, see Riby, 2004), a wide variety of fasting regimes is employed across studies measuring CHO effects on behavior and the moderating influence of such methodological decisions is not as yet clear.

Conclusion:

Sugar intake and mood swings have a complicated and multidimensional interaction. Research is beginning to

indicate that excessive or frequently sugar consumption may influence mood instability, including higher feelings of fatigue, irritability, and in certain cases, symptoms of anxiety and depression, even though short-term sugar intake may offer a momentary sense of pleasure or energy boost. The first “sugar high” is frequently followed by a sharp decline in blood glucose levels, which can lead to depressive mood swings. Habitually consuming large amounts of sugar can also affect inflammation, hormone balance, and brain function, all of which can have an adverse effect on mental health. A balanced diet, moderation, and mindful eating seem to be essential for mood regulation and psychological well-being. To better understand this relationship and provide sensible dietary recommendations, more longitudinal and mechanistic research is required.

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