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Modification of aftertaste with a menthol mouthwash reduces food wanting, liking, and *ad libitum* intake of potato crisps

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ABSTRACT

This research investigated the effect of modifying the aftertaste of potato crisps on (1) temporal sensory perception and (2) appetite using three mouthwash conditions (no mouthwash, a water mouthwash, and a menthol mouthwash). For the sensory study, 17 screened female subjects were trained on the Temporal Dominance of Sensations (TDS) methodology. Subjects undertook TDS to monitor all sensory attributes during the mastication of a 2 g crisp until swallowing (at 20s), then conducted the mouthwash, and then continued the TDS task to monitor aftertaste until 90s. For the appetite study, 36 subjects (18 male, 18 female) completed 100 mm Visual Analogue Scales (VAS) for desire, liking, hunger, and thirst, followed by an *ad libitum* eating task. For the VAS scales testing, subjects chewed and swallowed a 2 g crisp, and then immediately conducted the mouthwash before completing the VAS scales. For the *ad libitum* task, subjects were given 12 min to consume as many crisps as they desired on a plate (up to 50 g). Every three minutes they were required to conduct a mouthwash. TDS results showed that in comparison with no mouthwash, the water mouthwash significantly reduced aftertaste attributes such as savoury, salty, and fatty mouthcoating, and the menthol mouthwash significantly increased aftertaste attributes of cooling, minty, and tingly. The water mouthwash did not influence desire and liking of crisps, or hunger and thirst. The water mouthwash did not influence *ad libitum* intake of the crisps over a 12 min period. The menthol mouthwash significantly reduced desire and liking of the crisps, as well as hunger and thirst. Furthermore, the menthol mouthwash significantly reduced *ad libitum* crisp intake by 29% over the 12 min period.

1. Introduction

Excessive snacking of energy dense foods plays a significant role in the growth of the obesity epidemic (Forslund, Torgerson, Sjostrom, & Lindroos, 2005). Consumers, nutritionists, and food scientists are all seeking novel approaches to reduce the quantity that such products are consumed in. One approach to reduce energy intake is through the modification of sensory properties of foods (McCrickerd & Forde, 2015). Increasing oro-sensory exposure has been shown to increase satiety through the reduction of sip size in beverages (Weijzen, Smeets, & de Graaf, 2009), and the texture of solid foods has been shown to increase satiety as harder foods require greater oral processing effort than soft foods (Forde et al., 2013a,b). An increase of retronasal aroma release has also been shown to increase satiety (Ruijschopa, Boelrijk, de Ru, de Graaf, & Westerterp-Plantenga, 2008), and in some cases can influence food intake (Ramaekers, Luning et al., 2014).

Promising research is also emerging by changing the type of aroma, where the presence of incongruent odours was found to decrease appetite (Ramaekers, Boesveldt, Gort et al., 2014; Ramaekers, Boesveldt, Lakemond et al., 2014). Ramaekers, Boesveldt, Gort et al. (2014) and Ramaekers, Boesveldt, Lakemond et al. (2014) showed that where an odour differed greatly from the food by which participants were questioned, appetite decreased. Savoury aromas decreased the appetite for sweet foods, and sweet aromas decreased the appetite for savoury foods. Non-food odours also decreased appetite. This research somewhat challenges conventional thinking in regards to sensory specific

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satiety (SSS) (Rolls & Rolls, 1997; Rolls, Rolls, Rowe, & Sweeney, 1981), but offers significant potential for appetite and food intake control. Furthermore, the presence of a particular odour has been shown to promote or 'prime' the selection of foods with associated sensory properties. Gaillet, Sulmont-Rossé, Issanchou, Chabanet, & Chambaron (2013) and Gaillet-Torrent, Sulmont-Rossé, Issanchou, Chabanet & Chambaron, (2014) showed that priming subjects with a melon scent caused an increase in the likelihood to select vegetables in a starter from a menu, and priming subjects with a pear scent increased the likelihood to choose desserts with fruit.

It is hypothesised that changing sensory perception via a mouthwash after swallowing could modify aftertaste in a way that reduced desire for unhealthy snacks. It is possible this could be achieved by removing the aftertaste generated by unhealthy snacks with a water mouthwash, or by the addition of a mouthwash with an incongruent sensory profile to the food being consumed. This could lead to the development of practical strategies for consumers to curb their snacking behaviour, such as intervening during a snacking occasion by consuming an everyday product that has a contrasting taste profile shown to suppress appetite for high fat snack. In years to come, it may also be possible develop the technology where incongruent tastes can be released from within unhealthy products after a specific period of time into an eating event, to prevent overconsumption.

One compound which may provide a suitable sensory profile to reduce the intake of such snacks is menthol. For a salty, high fat snack such as crisps, menthol offers a complete sensory contrast, through minty, cooling and tingling sensations (Eccles, 1994). Its sensation is linked to a number of everyday products that are not associated with the intake of food, such as toothpaste, chewing gum, and dental mouthwash.

To assess the modification of aftertaste using a mouthwash, a dynamic sensory method is needed to monitor changes in perception with time. The Temporal Dominance of Sensations (TDS) technique is a relatively new sensory methodology (Labbe, Schlich, Pineau, Gilbert, & Martin, 2009) used to assess changes in multiple sensory attributes with time: throughout the process of mastication (Hutchings, Foster, Hedderley, & Morgenstern, 2014a) and after swallowing (Ng et al., 2012). While some earlier techniques have allowed several attributes to be monitored at the same time (Duizer, Bloom, & Findlay, 1997; Green & Hayes, 2003), TDS allows numerous attributes (typically 8–12) to be monitored at the same time, where subjects are required to select the most dominant sensory attribute, and change their selection if and when they feel the most dominant attribute changes. The training required to assess 8–12 attributes with TDS is also very small in comparison to the large amounts of time that would be required for traditional time intensity methods (Pineau et al., 2009). Consequently, the TDS technique has the potential to effectively assess the sensory profile of the mastication of a solid food product immediately followed by the aftertaste of a mouthwash within the same chewing, swallowing, and mouthwash sequence.

The aim of the study was to:

(1) Assess the influence of a water mouthwash and menthol mouthwash on the aftertaste of potato crisps using the Temporal Dominance of Sensations methodology (in comparison with a 'no mouthwash' control).
(2) Assess the effect of a water mouthwash and menthol mouthwash on food liking, desire, hunger, thirst, and *ad libitum* food intake of potato crisps (in comparison with a 'no mouthwash' control).

2. Methodology

2.1. Overall design

This research was approved by the University College Dublin Human Ethics Committee (Application LS-E-15-90) and all subjects provided informed consent prior to participation. The research was broken into two studies. The first study sought to establish the sensory implications of each mouthwash treatment on the aftertaste of potato crisps using the Temporal Dominance of Sensations (TDS) methodology. The second study sought to understand the influence the mouthwashes were having on appetite for potato crisps using visual analogue scales (VAS) and an *ad libitum* eating task. The two studies were conducted separately with different participants. This was designed to ensure naïve consumers could be tested for appetite using VAS scales, without the confounding effect of using a complex sensory method like TDS at the same time. It also allowed for appetite to be measured immediately after the mouthwash was applied. The essence of the work was that in both studies subjects would masticate and then swallow a 2 g crisp, before immediately applying a mouthwash to influence aftertaste. Mastication time (from the commencement of chewing until swallowing) was controlled at 20s for the sensory study. For the appetite study subjects were instructed to chew and swallow in a manner that felt natural and comfortable for them. The methodology used for the sensory study is summarised in Fig. 1, and the methodology used for the appetite study is summarised in Fig. 2.

2.2. Treatments

The crisps used for both studies were ready salted crisps (Pringles®, Kelloggs, Poland) (2161 kJ per 100 g). Three mouthwash treatments were used in both studies: 1 – no mouthwash, 2 - a water mouthwash using demineralised water (VWR Chemicals, Dublin, Ireland), 3 – a mouthwash of menthol at 0.4 g/L. Both mouthwash treatments involved subjects washing 20 mL of the mouthwash for 10s, expectorating the entire sample, and then repeating with another 20 mL of mouthwash (fresh mouthwash, not the same sample) for 10s and expectorating the entire sample. The mouthwash was conducted twice to ensure a thorough wash of the mouth and/or application of menthol taste. The preparation of a 0.4 g/L menthol solution involved dissolving 0.2 g L-Menthol crystals (99%, Sigma Aldrich, Steinheim, Germany) in 5 mL of food grade ethanol (Sedacol, 96%, Selby, UK). Demineralised water (500 mL) (VWR Chemicals, Dublin, Ireland) was then heated to 60 °C, and the ethanol-menthol mixture was then added to the water, and mixed in a sealed container. The final menthol solution had an ethanol content of 1% v/v. All solutions and crisps were served at 20 °C in isolated sensory booths of standard dimensions, with a room temperature of 20 °C and standard white light.

2.3. Palate cleansing procedure

Throughout the sensory and appetite studies (prior to each crisp (eg a chew/swallow/mouthwash sequence) and prior to the *ad libitum* task), subjects were asked to cleanse their mouth and then wait five minutes. This involved washing the mouth with 20 mL of mineral water (Ballygowan®, Britvic Ireland Ltd., Dublin, Ireland) for 10s, expectorating, and then washing with another 20 mL of mineral water for 10s, expectorating, and then lightly drying surface of the tongue with a piece of paper towel to remove excess moisture (the paper towel was then immediately disposed of), before waiting five minutes. This approach was designed to minimise any lingering flavours from the crisps or mouthwashes, and to allow time for the moisture content in the mouth to equilibrate.