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Aroma-related cross-modal interactions for sugar reduction in milk desserts: Influence on consumer perception

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ABSTRACT

Reformulation of industrialized products has been regarded as one of the most cost-effective strategies to reduce sugar intake. Although non-nutritive sweeteners have been extensively used to reduce the added sugar content of these products, increasing evidence about the existence of compensatory energy intake mechanisms makes it necessary to develop alternative strategies to achieve rapid sugar reductions. In this context, the aim of the present work was to evaluate aroma-related cross modal interactions for sugar reduction in vanilla milk desserts. In particular, the influence of increasing vanilla concentration and the joint increase of vanilla and starch concentration on consumer sensory and hedonic perception was assessed. Two studies with 100 consumers each were conducted, in which a total of 15 samples were evaluated. For each sample, consumers rated their overall liking and answered a check-all-that-apply (CATA) question comprising 12 flavour and texture terms. Sugar reduction caused significant changes in the flavour and texture characteristics of the desserts. An increase in vanilla concentration had a minor effect on their sensory characteristics. However, increasing both vanilla and starch concentration led to an increase in vanilla flavour and sweetness perception and reduced changes in consumer hedonic perception. These results showed the potential of aroma-related cross modal interactions for minimizing the sensory changes caused by sugar reduction. These strategies could contribute to product reformulation without the need to use non-nutritive sweeteners.

1. Introduction

Excessive sugar consumption has become a significant health problem worldwide as it has linked to the increasing prevalence of obesity (Vio & Uauy, 2007). Added sugar consumption contributes to 500 cal per day, corresponding to 17–25% of the recommended calorie intake (Lustig, Schmidt, & Brindis, 2012). In addition, excessive sugar intake has been linked to several metabolic abnormalities and adverse health problems, such as type 2 diabetes, cardiovascular diseases and dental caries (Johnson et al., 2009; Moynihan & Kelly, 2014; Te Morenga, Mallard, & Mann, 2013). For this reason, it has been recommended to restrict the intake of sugars to <5–10% of the total daily energy consumption (World Health Organization and Agriculture Organization of the United Nations, 2003; Scientific Advisory Committee on Nutrition, 2014). This situation makes it necessary to develop strategies to reduce sugar consumption worldwide.

Sugar is added to a large proportion of processed foods (Vio & Uauy, 2007). Therefore, one of the possible strategies for rapidly decreasing sugar consumption of the population is to reduce the added sugar content of these products (MacGregor & Hashem, 2014). One of the main challenges faced in product reformulation is related to changes in product flavour and texture, which are determinant of product success in the marketplace (van Raaij, Hendriksen, & Verhagen, 2009). Considering that most consumers are not willing to compromise on sensory and hedonic aspects of products for their healthfulness (Civille & Oftedal, 2012), it is necessary to develop reformulation strategies that allow to gradually reduce the added sugar content of product without consumer awareness.

The addition of non-nutritive sweeteners has been one of the most common strategies to reduce the added sugar content of a wide range of food products (Dubois & Prakash, 2012). However, non-nutritive sweeteners can convey bitter and metallic off-flavours, which can negatively influence consumer hedonic perception (Cardoso & Bolini, 2008; Markey, Lovegrove, & Methven, 2015; Zorn, Alcaire, Vidal, Giménez, & Ares, 2014). In addition, several studies have suggested that the potential benefits of non-nutritive sweeteners for preventing weight gain may be hindered by compensatory energy intake mechanisms (Gardner et al., 2012; Mattes & Popkin, 2009). For these reasons, reducing the added sugar content of processed products without the addition of non-nutritive has been recommended (Yang, 2010).

An alternative strategy to achieve rapid sugar reductions is to increase sweetness perception during product reformulation using multisensory integration principles (Stieger & van de Velde, 2013). Taste

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perception is affected by aroma compounds through cross-modal aroma-taste interactions, which indicates that the perceived intensity of a taste can be modulated by aroma (Poinot, Arvisenet, Ledauphin, Gaillard, & Prost, 2013). In particular, sweetness perception has been reported to be enhanced by the addition of aromas related to sweet products, such as vanilla, caramel or fruity notes, even at subthreshold concentrations, due to the associations formed during previous exposures with complex stimuli (Boakes & Hemberger, 2012; Burseg, Camacho, Knoop, & Bult, 2010; Labbe & Martin, 2009; Labbe, Rytz, Morgenegg, Ali, & Martin, 2007; Murphy & Cain, 1980; Tournier et al., 2009). However, cross-modal aroma–taste interactions have been reported to be aroma- and product-specific. Therefore, successful application of aroma-induced sweetness enhancement in sugar reduced products requires careful screening of both aroma compounds and concentrations (Stieger & van de Velde, 2013).

Apart from influencing taste perception, sugar reduction can also influence texture perception (van Raaij et al., 2009), as previously reported by Oliveira et al. (2015) in probiotic chocolate-flavoured milk, by Drewnowski, Nordensten, and Dwyer (1998) in cookies, and by Biguzzi, Schlich, and Lange (2014) in biscuits. Therefore, it is necessary to compensate the loss in matrix structure due to sugar reduction through the addition of bulking agents (Kaufmann & Palzer, 2011). Interactions between texture and aroma perception have been reported in the literature (Poinot et al., 2013). Therefore, research on texturizers on consumer sensory and hedonic perception of sugar-reduced samples is still necessary, as highlighted by Chollet, Gille, Schmid, Walther, and Piccinali (2013).

In this context, the aim of the present work was to evaluate the use of cross-modal aroma–taste interactions and bulking agents for reducing the added-sugar content of vanilla milk desserts. In particular, the influence of vanilla concentration and the joint increase of vanilla and starch concentration on consumer sensory and hedonic perception was assessed. Milk desserts are dairy products widely consumed worldwide by several groups of consumers on an almost daily basis, which have a positive healthful image despite their high added sugar concentration (15–20%) (Ares, Giménez, & Gámbaro, 2008).

2. Materials and methods

Two studies were carried out to evaluate the influence of an increase of vanilla and a joint increase of vanilla and starch concentration on consumer sensory and hedonic perception of sugar-reduced vanilla milk desserts. In a first study, ten milk desserts with different sugar content were formulated by increasing vanilla concentration to enhance sweetness perception and starch to compensate the texture changes caused by sugar reduction. Based on the results of the first study, a second study was conducted with different vanilla and starch concentrations.

2.1. Samples

Vanilla milk dessert samples with different sugar, vanilla and starch concentration were formulated. All samples were manufactured using the following base formulation: 12% powdered milk (Conaprole, Uruguay), 0.1% polyphosphate, 0.02% carrageenan (Ticaloid® 710H Stabilizer — Texture Innovation Center, TIC GUMS, Philadelphia, USA), 0.0025% egg yellow colouring and filtered tap water. The first study involved 10 samples, whereas 5 samples were included in the second study. All samples were obtained by varying the concentration of modified starch (Purity HPC), vanilla flavour (SI 10014 – Waltary SA, Montevideo, Uruguay) and commercial sugar (Alcoholes del Uruguay S.A., Bella Unión, Uruguay), as shown in Table 1. The vanilla and starch concentrations in the first study were selected based on pilot testing.

Samples were prepared using Termomix TM 31 (Vorwerk Mexico S. de R.L. de C.V., Mexico D.F., Mexico). All the ingredients were mixed and heated at 90 °C for 5 min. After that, both vanilla flavour and colouring were added and the dispersion was mixed again with a powerful agitation (100 rpm) for 1 min. The desserts were placed in glass containers and stored under refrigeration (4–7 °C) for 24 h prior to testing. Then, desserts were served (20 g) in plastic containers identified with random three-digit codes at 8 °C.

Table 1
Formulation of the vanilla milk desserts included in the two studies.

Study	Sample	Sugar (%)	Sugar reduction (%)	Starch (%)	Vanilla (%)
1	0S4.2V0.4	20	0	4.2	0.4
	20S4.2V0.4	16	20	4.2	0.4
	20S4.2V0.6	16	20	4.2	0.6
	20S5.2V0.6	16	20	5.2	0.6
	40S4.2V0.4	12	40	4.2	0.4
	40S4.2V0.6	12	40	4.2	0.6
	40S5.2V0.6	12	40	5.2	0.6
	60S4.2V0.4	8.0	60	4.2	0.4
	60S4.2V0.6	8.0	60	4.2	0.6
	60S5.2V0.6	8.0	60	5.2	0.6
2	0S4.2V0.4	20	0	4.2	0.4
	10S4.2V0.4	18	10	4.2	0.4
	20S4.2V0.8	16	20	4.2	0.8
	20S4.6V0.6	16	20	4.6	0.6
	40S5.0V0.8	12	40	5.0	0.8

Coding of the samples indicates sugar reduction percentage (0, 10, 20, 40 or 60), followed by the starch concentration (S) and vanilla concentration (V).

2.2. Participants

A total of 200 consumers were involved in the present work, 100 in each study. Participants were recruited from the consumer database of Sensometrics & Consumer Science group (Universidad de la República, Uruguay) based on their consumption of milk desserts (at least once a month) and availability to participate in the study. They were aged between 17 and 55 and were 71% female. Participants signed an informed consent agreement and received a gift for their participation.

2.3. Experimental procedure

The experimental procedure in both studies was identical. Participants were asked to try the desserts, rate their overall liking using a 9-point hedonic scale (1 = dislike very much and 9 = like very much) and answer a check-all-that-apply (CATA) question to describe their sensory characteristics. The CATA question was composed of 12 flavour and texture terms: *sweet, very sweet, barely sweet, vanilla flavour, firm, thick, creamy, smooth, liquid, milky flavour, tasteless* and *gummy*. Terms were selected based on previous consumer studies with the same product category (Ares, Giménez, Barreiro, & Gámbaro, 2010; Vidal et al., 2014). Presentation order of terms was balanced between and within participants, as recommended by Ares et al. (2014).

In each study, samples were presented following a presentation order balanced for order and carry over effects (Williams' Latin Square design). Still mineral water was used for rinsing between samples. Testing took place in a sensory laboratory that was designed in accordance with ISO 8589 (ISO, 2007), under artificial daylight and temperature control (22 °C). Data were collected using Compusense Cloud (Compusense Inc., Guelph, Ontario, Canada).

2.4. Data analysis

In each study, overall liking scores were analysed using a mixed linear model considering sample as fixed effect and consumer as random effect. Tukey's test was used for post-hoc comparison of means. A confidence level of 95% was considered.

Data from the CATA question were analysed by determining the frequency of use of each term for describing each sample. Significant differences among samples were evaluated using Cochran's Q Test (Manoukian, 1986). The sign test was used for pairwise comparisons.