Significant sugar-reduction in dairy products targeted at children is possible without affecting hedonic perception.
Abstract

The objective of the present study was to evaluate children's hedonic sensitivity to sugar reduction in three dairy products: vanilla milk desserts, chocolate-flavored milk, and vanilla yogurt. For each product, a regular sample and five samples with different reduction in added-sugar content were formulated. The regular sample contained the sugar content of commercial products available in the marketplace. The reduction in added-sugar content ranged between 10.0 and 41.0%. A total of 126 children (8 to 13 years old) participated in the study. An A-not A test was used to evaluate children's hedonic sensitivity to sugar reduction. Sugar reductions up to 27% in chocolate-flavored milk and vanilla yogurt, and up to 19% in vanilla milk desserts, did not cause significant changes in children's hedonic reaction. These results confirm that sugar-reduction strategies can be easily implemented in the dairy industry without significant risk of affecting sample appreciation and market share.

Keywords: sugar reduction; dairy products; children; reformulation.
1. Introduction

Sugar intake has been identified as one of the most important dietary factors for childhood overweight and obesity (Newens & Walton, 2016; WHO, 2015). Children frequently consume processed products with high added sugar concentration (Azaïs-Braesco, Sluik, Maillot, Kok, & Moreno, 2017; Louie, Moshtaghian, & Rangan, 2016). Thus, most of processed products targeted at children have been reported to contain excessive sugar content (Boulton et al., 2016; Elliott, 2008; Giménez, Saldamando, Curutchet, & Ares, 2017).

Dairy products are an important source of added sugar in children's diet (Azaïs-Braesco et al., 2017; Boulton et al., 2016; Poti, Slining, & Popkin, 2014). Recently, Moore, Horti, & Fielding (2018) reported that only 2% of the yogurts targeted at children in British supermarkets can be categorized as low in sugar, whereas dairy desserts aimed at children's lunch boxes had a high content of sugar (over 16%). Considering that dairy products are recommended as part of children's diets due to their nutritional value (Campmans-Kuijpers, Singh-Povel, Steijins, & Beulens, 2016; Dror & Allen, 2014), a reduction in added sugar seems necessary to reduce children's sugar intake.

Sugar content of dairy products can be gradually reduced so that consumers get used to lower sugar concentrations without noticing any differences (MacGregor & Hashem, 2014). Implementation of this approach requires estimation of difference thresholds, i.e. the reduction in added sugar concentration that causes a perceivable change in 50% of consumers' (McCain, Kaliappan, & Drake, 2018). Despite advances by the food industry in the field of sugar reduction (Moore, Sutton, & Hancock, 2020), open information regarding implementation of sugar reduction strategies remains scarce. Previous studies conducted with adult consumers have shown that sugar reductions of 20-30% may be achieved without compromising acceptance (Alcaire, Antúnez, Vidal, Giménez & Ares, 2017; Hoppert et al., 2013; Li, Lopetcharat, & Drake, 2015; Lima, Ares & Deliza, 2018; Oliveira et al., 2016). However, information about children's hedonic sensitivity to sugar reduction in dairy products is limited. Only a few studies have been
published assessing sugar reduction in chocolate-flavored milk (Li, Lopetcharat, & Drake, 2015; Li, Lopetcharat, Qiu, et al., 2015) and vanilla milk desserts (Velázquez, Vidal, Varela, & Ares, 2020).

In this context, the objective of the present study was to evaluate children's hedonic sensitivity to sugar reduction in three highly consumed dairy products: vanilla milk desserts, chocolate-flavored milk, and vanilla yogurt.

2. Materials and Methods

2.1 Samples

Three highly consumed dairy products among children were studied: vanilla milk desserts, chocolate-flavored milk, and vanilla-flavored yogurt. For each product, a regular sample and five samples with different reductions in added-sugar content were formulated. The regular sample contained the sugar content of commercial products available in the Uruguayan marketplace. Reduction in added-sugar content ranged between 10.0 and 41.0% (Table 1). Also, for each product category, a warm-up sample was formulated, identical to the regular sample but with a different vanilla flavoring or different vanilla concentration, with the purpose of sample familiarization before the actual test.

2.1.1 Vanilla milk desserts

All samples were prepared using a base formulation containing UHT whole milk (3.2% fat and 4.7% carbohydrates) (Conaprole, Uruguay), 4.3% w/w starch (Purity HPC, Ingredion, Brazil), 0.4% v/w vanilla (Aryes, Jaraguá do Sul, Brazil), 0.1% w/w polyphosphate and 0.02% w/w carrageenan (Ticaloid® 710H Stabilizer - Texture Innovation Center, TIC GUMS, PA, USA). Sugar (Alcoholes del Uruguay S.A., Bella Unión, Uruguay) concentration was varied as detailed in Table 1. Samples were prepared using a Thermomix (Vorwerk Mexico S. de R.L. de C.V., Mexico City, Mexico).
Powdered ingredients were mixed with the whole milk and heated at 90°C under constant stirring for 5 min. After heating process, the vanilla was added to the mixture and stirred for 1 min. Desserts were placed in glass jars and stored for 24 h at 6-8°C prior to the evaluation.

2.1.2 Chocolate-flavored milk

Chocolate-flavored milk was prepared using UHT whole milk, 1% w/w alkaline cocoa powder (Aryes, Montevideo, Uruguay), 0.08% w/w carrageenan, 0.05% v/w vanilla and varying concentrations of sugar (Table1). Samples were prepared using a Thermomix by adding the powdered ingredients to whole milk, previously heated at 70°C for 3 min, and dispersed for 1 min. The mixture was kept at 70°C for 4 min under constant stirring. Then, vanilla was added to the mixture and stirred for 1 min. Finally, the samples were cooled down to 20°C in ice water and placed in glass jars. Samples were stored for 24 h at 6-8°C until their evaluation.

2.1.3 Vanilla yogurt

Samples were prepared using plain skimmed yogurt (Conaprole, Uruguay), 0.4% v/w vanilla flavoring and varying concentrations of powdered sugar (Table 1). All ingredients were mixed in a Thermomix for 10 min under gently stirring. Then, samples were placed in glass jars and stored for 24 h at 6-8°C until their evaluation.

2.2 Participants

A total of 126 children (8 to 13 years old (M=10.6 years old, SD=1.3), 52% girls) were recruited from three institutions in Montevideo, Uruguay (one school and two social clubs). For every child, one of the parents signed an informed consent form to allow their children to participate in the study, whereas children provided informed assent to participate through the software used for data collection. It was explained that their participation was voluntary and that they could withdraw at any time. Ethical approval
was obtained from the Ethics Committee of the School of Chemistry of Universidad de la República (Protocol No 101900-000090-19).

Children were invited to participate in three tasting sessions, one per product category. Since sessions took place on different days, some children were unable to complete all sessions. The number of children who tasted each of the products was 54 for vanilla milk desserts, 64 for chocolate-flavored milk and 76 for vanilla yogurt. The order in which children evaluated the three product categories was balanced across the three institutions.

2.3. Experimental procedure

A standard A-Not A test was used to evaluate children’s hedonic sensitivity to sugar reduction in the three product categories. This test was regarded as a good methodological option for children due to its simplicity and its lower cognitive load compared to other discriminative tests. The A-not A test is an overall difference test where participants are first familiarized with the reference product. Then, they evaluate one product at a time and decide if the test product is the same or different to the reference (Van Hout, Hautus, & Lee, 2011).

Tasting sessions were divided into two sections: a familiarization step and sample tasting. The study took place at the school or social club. Children performed the study in groups of 5-6 children with the assistance of 3 researchers. Each session lasted maximum 15 minutes.

The test was presented as a memory game using CompuSense Cloud (CompuSense Inc., Guelph, Canada) on Ipads (Apple Inc., Cupertino, USA). The instructions were given using explanatory videos featuring a cartoon character. After each video, a researcher verbally repeated the instructions and asked children if they had any questions.

Samples were presented in plastics cups, coded with 3-digit random numbers at 8°C. For evaluation of milk desserts, children received a plastic spoon for each of the
samples. Still mineral water was used as palate cleaner. A text was added to the test to remind children of rinsing their mouth after assessing each of the samples. Children completed the test at their own pace, as no specific timing was set.

2.3.1. Task Familiarization

Children were familiarized with the methodology through the evaluation of apple images. First, an image of a reference apple was presented. Children were asked to watch it carefully and to try to remember its characteristics. Then, the reference apple image and a defective apple image were presented one by one. For each of the images, they were asked to indicate if they liked the apple image as much as they liked the reference apple image, using the response options “Yes”, “No” or “I don’t know”.

2.3.2. Sample familiarization

Before the actual sample tasting, children had to complete a warm-up task for sample familiarization. Children were presented with the reference sample, named "secret formula”. They were asked to try it and to remember its characteristics. Then, two samples (again the reference and the warm-up sample) were presented. For each of the samples, they were asked to indicate if they liked the sample as much as they liked the reference sample using the response options “Yes”, “No” or “I don’t know”.

2.3.3. Sample tasting

After completing the warm-up task, children were asked to taste the reference sample again. Then, they were presented with six samples (the reference and the five sugar-reduced samples, c.f. Table 1) one by one, following a Williams' Latin square balanced design. For each of the samples, they were asked if they liked the sample as much as they liked the reference sample. Children could re-taste the reference sample if needed. Researchers were available to assist children during the test.
2.3 Data analysis

A Thurstonian approach was used to estimate underlying sensory difference (d’) between the control and the sugar reduced samples using the sensR package for R software (Brockhoff & Christensen, 2010). For each product category, the d’ values between the reference sample and each of the sugar reduced samples were estimated using a standard A-Not A model. The calculation was performed using the number of children who stated that they liked the sugar-reduced sample as much as the reference (“Yes” responses). For the reference sample, pooled data from the warm-up and main task were used. The “Don’t know” responses were not considered in the analysis (<14% of the total responses).

3. Results and Discussion

The present work aimed at providing insights for the design of sugar-reduction strategies of dairy products targeted at children. For this purpose, children’s sensitivity to sugar reduction was studied, in three highly consumed dairy products, using the A-not-A test. Results from the familiarization step with apple images showed that children understood the task: the percentage of children who reported liking the reference apple (when it was presented blind) as much as the reference was higher than 80% across the three sessions.

Table 2 shows the d’ estimates and their corresponding standard errors, which measure the sensory difference between each of the sugar reduced samples and the reference sample (without sugar reduction) (Lee & O’Mahony, 2004). As expected, d’ values were not significantly different from 0 for the smallest added sugar reductions for the three product categories. For vanilla milk desserts, d’ was significantly different from 0 when added sugar reduction was 27.1% or higher. This suggests that sugar reductions up to approximately 25% would be possible without significantly affecting children’s hedonic perception. Similar results were obtained for chocolate-flavored milk and vanilla...
yogurt. As shown in Table 2, d’ values were significantly different from 0 when sugar
total was 34.4% or higher, suggesting that in these products added sugar can be
reduced up to 34% without affecting children’s hedonic perception.

Results from the present work are similar to those reported by other authors when
evaluating adults and children’s hedonic sensitivity to sugar reduction in different food
matrices, including dairy products (Alcaire et al., 2017; Chang & Chiou, 2006; Chollet,
Gille, Schmid, Walther, & Piccinali, 2013; Hoppert et al., 2013; Lima et al., 2018; Oliveira
et al., 2016; Pineli et al., 2016; Velázquez et al., 2019). Although children have been
reported to have a heightened preference for sugar as compared to adults (Zandstra &
De Graaf, 1998), evidence from this work suggests that the added sugar content of dairy
products targeted at children can be reduced up to 25-30% without affecting
acceptability.

Interestingly, hedonic sensitivity to sugar reduction was largely similar across the
three product categories. As shown in Table 2, children were slightly less tolerant to
sugar reduction in vanilla milk desserts as compared to chocolate-flavored milk and
vanilla yogurt. This difference could be explained by changes in thickness and
creaminess caused by sugar reduction in milk desserts (Alcaire et al., 2017; Velázquez
et al., 2019), which might not be so relevant in yogurt and flavored milk.

Until now, one of the most popular strategies to reduce sugar content in dairy
products has been the use of non-nutritive sweeteners to maintain sweet taste (Moore
et al., 2019). Results from the present work suggest that relevant straight sugar
reductions, without compensating with extra sweeteners, could be rapidly achieved in
products targeted at children. Apart from its contribution to lowering sugar intake, gradual
sugar reduction in dairy products could reduce children exposure to sweet taste,
contributing to reducing their sweetness preferences (Mennella & Bobowski, 2015;
Nicklaus & Remy, 2013).
Conclusions

Results from the present work suggest that added-sugar can be reduced up to 25% in dairy products targeted at children without affecting their hedonic perception. This information is highly valuable for sensory scientists and food technologists and confirms that sugar-reduction strategies can be swiftly implemented in the dairy industry without significant risks of affecting market share. In this sense, these results stress the lack of justification of the slow response of some dairy industries worldwide to reducing the sugar content and sweet taste of their products targeted at children.

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References

Alcaire, F., Antúnez, L., Vidal, L., Giménez, A., & Ares, G. (2017). Aroma-related cross-modal interactions for sugar reduction in milk desserts: Influence on consumer perception. Food Research International, 97, 45–50. https://doi.org/https://doi.org/10.1016/j.foodres.2017.02.019

Azaïs-Braesco, V., Sluik, D., Maillot, M., Kok, F., & Moreno, L. A. (2017). A review of total & added sugar intakes and dietary sources in Europe. Nutrition Journal, 16(1), 6. https://doi.org/10.1186/s12937-016-0225-2

Boulton, J., Hashem, K. M., Jenner, K. H., Lloyd-Williams, F., Bromley, H., & Capewell, S. (2016). How much sugar is hidden in drinks marketed to children? A survey of
fruit juices, juice drinks and smoothies. BMJ Open, 6(3), e010330.
https://doi.org/10.1136/bmjopen-2015-010330

Brockhoff, P. B., & Christensen, R. H. B. (2010). Thurstonian models for sensory
discrimination tests as generalized linear models. Food Quality and Preference,
21(3), 330–338. https://doi.org/https://doi.org/10.1016/j.foodqual.2009.04.003

Campmans-Kuijpers, M. J. E., Singh-Povel, C., Steijns, J., & Beulens, J. W. J. (2016).
The association of dairy intake of children and adolescents with different food and
nutrient intakes in the Netherlands. BMC Pediatrics, 16, 2.
https://doi.org/10.1186/s12887-015-0524-3

Chang, M. H., & Chiou, W. B. (2006). Differential threshold and psychophysical power
function of sweetness sensation: Applied psychophysics and prospect theory on
formulating baking products. Journal of Sensory Studies, 21(5), 534-551.
https://doi.org/10.1111/j.1745-459X.2006.00078.x

Chollet, M., Gille, D., Schmid, A., Walther, B., & Piccinali, P. (2013). Acceptance of sugar
reduction in flavored yogurt. Journal of Dairy Science, 96(9), 5501–5511.
https://doi.org/https://doi.org/10.3168/jds.2013-6610

Dror, D. K., & Allen, L. H. (2014). Dairy product intake in children and adolescents in
developed countries: trends, nutritional contribution, and a review of association
with health outcomes. Nutrition Reviews, 72(2), 68–81.
https://doi.org/10.1111/nure.12078

Elliott, C. (2008). Assessing ‘fun foods’: nutritional content and analysis of supermarket
foods targeted at children. Obesity Reviews, 9(4), 368–377.
https://doi.org/10.1111/j.1467-789X.2007.00418.x

Giménez, A., Saldamando, L. de, Curutchet, M. R., & Ares, G. (2017). Package design
and nutritional profile of foods targeted at children in supermarkets in Montevideo,
Uruguay. Cadernos de Saude Publica, 33(5), e00032116.
https://doi.org/10.1590/0102-311X00032116

Hoppert, K., Zahn, S., Jänecke, L., Mai, R., Hoffmann, S., & Rohm, H. (2013). Consumer
acceptance of regular and reduced-sugar yogurt enriched with different types of dietary fiber. *International Dairy Journal*, 28(1), 1–7. https://doi.org/https://doi.org/10.1016/j.idairyj.2012.08.005

Lee, H.-S., & O'Mahony, M. (2004). Sensory difference testing: Thurstonian models. *Food Science and Biotechnology*, 13, 841–847.

Li, X. E., Lopetcharat, K., & Drake, M. A. (2015). Parents' and Children's Acceptance of Skim Chocolate Milks Sweetened by Monk Fruit and Stevia Leaf Extracts. *Journal of Food Science, 80*(5), S1083–S1092. https://doi.org/10.1111/1750-3841.12835

Li, X. E., Lopetcharat, K., Qiu, Y., & Drake, M. A. (2015). Sugar reduction of skim chocolate milk and viability of alternative sweetening through lactose hydrolysis. *Journal of Dairy Science, 98*(3), 1455–1466. https://doi.org/https://doi.org/10.3168/jds.2014-8490

Lima, M., Ares, G., & Deliza, R. (2018). How do front of pack nutrition labels affect healthfulness perception of foods targeted at children? Insights from Brazilian children and parents. *Food Quality and Preference, 64*(May 2017), 111–119. https://doi.org/10.1016/j.foodqual.2017.10.003

Louie, J. C. Y., Moshtaghian, H., Rangan, A. M., Flood, V. M., & Gill, T. P. (2016). Intake and sources of added sugars among Australian children and adolescents. *European Journal of Nutrition, 55*(8), 2347–2355. https://doi.org/10.1007/s00394-015-1041-8

Macgregor, G. A., & Hashem, K. M. (2014). Action on sugar—lessons from UK salt reduction programme. *Lancet, 383*(9921), 929–931. https://doi.org/10.1016/S0140-6736(14)60200-2

McCain, H. R., Kaliappan, S., & Drake, M. A. (2018). Invited review: Sugar reduction in dairy products. *Journal of Dairy Science, 101*(10), 8619–8640. https://doi.org/https://doi.org/10.3168/jds.2017-14347

Mennella, J. A., & Bobowski, N. K. (2015). The sweetness and bitterness of childhood: Insights from basic research on taste preferences. *Physiology & Behavior, 152*(Pt
Moore, J. B., Sutton, E. H., & Hancock, N. (2020). Sugar Reduction in Yogurt Products Sold in the UK between 2016 and 2019. *Nutrients, 12*(1), 171. https://doi.org/10.3390/nu12010171

Moore, J. B., Horti, A., & Fielding, B. A. (2018). Evaluation of the nutrient content of yogurts: a comprehensive survey of yogurt products in the major UK supermarkets. *BMJ Open, 8*(8), e021387. https://doi.org/10.1136/bmjopen-2017-021387

Newens, K. J., & Walton, J. (2016). A review of sugar consumption from nationally representative dietary surveys across the world. *Journal of Human Nutrition and Dietetics, 29*(2), 225–240. https://doi.org/10.1111/jhn.12338

Nicklaus, S., & Remy, E. (2013). Early Origins of Overeating: Tracking Between Early Food Habits and Later Eating Patterns. *Current Obesity Reports, 2*(2), 179–184. https://doi.org/10.1007/s13679-013-0055-x

Oliveira, D., Reis, F., Deliza, R., Rosenthal, A., Giménez, A., & Ares, G. (2016). Difference thresholds for added sugar in chocolate-flavoured milk: Recommendations for gradual sugar reduction. *Food Research International, 89*, 448–453. https://doi.org/10.1016/j.foodres.2016.08.019

Pineli, L. de L. de O., Aguiar, L. A. de, Fiusa, A., Botelho, R. B. de A., Zandonadi, R. P., & Melo, L. (2016). Sensory impact of lowering sugar content in orange nectars to design healthier, low-sugar industrialized beverages. *Appetite, 96*, 239–244. https://doi.org/10.1016/j.appet.2015.09.028

Poti, J. M., Slining, M. M., & Popkin, B. M. (2014). Where Are Kids Getting Their Empty Calories? Stores, Schools, and Fast-Food Restaurants Each Played an Important Role in Empty Calorie Intake among US Children During 2009-2010. *Journal of the Academy of Nutrition and Dietetics, 114*(6), 908–917. https://doi.org/10.1016/j.jand.2013.08.012

Van Hout, D., Hautus, M. J., & Lee, H. S. (2011). Investigation of test performance over repeated sessions using signal detection theory: Comparison of three nonattribute-
specified difference tests 2-AFCR, A-NOT A and 2-AFC. *Journal of Sensory Studies*, 26(5), 311-321. https://doi.org/10.1111/j.1745-459X.2011.00346.x

Velázquez, A. L., Vidal, L., Varela, P., & Ares, G. (2020). Cross-modal interactions as a strategy for sugar reduction in products targeted at children: Case study with vanilla milk desserts. *Food Research International*, 130, 108920. https://doi.org/https://doi.org/10.1016/j.foodres.2019.108920

WHO. (2015). Guideline: sugars intake for adults and children. World Health Organization. https://apps.who.int/iris/handle/10665/149782

Zandstra, E. H., & de Graaf, C. (1998). Sensory perception and pleasantness of orange beverages from childhood to old age. *Food Quality and Preference*, 9(1), 5–12. https://doi.org/https://doi.org/10.1016/S0950-3293(97)00015-3
Table 1. Added sugar concentration of the samples, for each of the three categories of dairy products considered in the study.

| Added sugar reduction (% w/w) | Added sugar content (% w/w) |         |         |         |
|------------------------------|-----------------------------|---------|---------|---------|
|                              |                            | Vanilla milk desserts | Chocolate-flavored milk | Vanilla yogurt |
| 0 (reference)                | 12.0                        | 7.0     | 11.0    |         |
| 10                           | 10.8                        | 6.3     | 9.9     |         |
| 19                           | 9.7                         | 5.7     | 8.9     |         |
| 27.1                         | 8.7                         | 5.1     | 8.0     |         |
| 34.4                         | 7.9                         | 4.6     | 7.2     |         |
| 41.0                         | 7.1                         | 4.1     | 6.5     |         |
Table 2. Estimates of $d'$ and their standard error for the comparison of the added sugar reduced samples and the reference sample in the A-not A test for the three product categories.

| Product category          | Added sugar reduction (%) | n* | $d'$  | Standard error | p-value |
|---------------------------|---------------------------|----|-------|----------------|---------|
| Vanilla milk desserts     | 10.0                      | 50 | 0.174 | 0.227          | 0.280   |
| (n=54)                    | 19.0                      | 50 | 0.320 | 0.227          | 0.110   |
|                           | 27.1                      | 49 | 0.582 | 0.224          | 0.008   |
|                           | 34.4                      | 49 | 1.018 | 0.226          | <0.001  |
|                           | 41.0                      | 51 | 1.072 | 0.227          | <0.001  |
| Chocolate-flavored milk   | 10.0                      | 63 | 0.188 | 0.216          | 0.853   |
| (n=64)                    | 19.0                      | 61 | 0.121 | 0.209          | 0.340   |
|                           | 27.1                      | 62 | 0.302 | 0.202          | 0.092   |
|                           | 34.4                      | 59 | 0.611 | 0.201          | 0.002   |
|                           | 41.0                      | 63 | 0.771 | 0.199          | <0.001  |
| Vanilla yogurt            | 10.0                      | 71 | 0.219 | 0.194          | 0.165   |
| (n=76)                    | 19.0                      | 70 | 0.066 | 0.198          | 0.430   |
|                           | 27.1                      | 72 | 0.074 | 0.195          | 0.413   |
|                           | 34.4                      | 69 | 0.373 | 0.191          | 0.036   |
|                           | 41.0                      | 70 | 0.539 | 0.189          | 0.003   |

Notes: * Children answering "Don't know" were excluded from the analysis. The $d'$ estimates of samples highlighted in bold are significantly different from 0.