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7 **Significant sugar-reduction in dairy products targeted at children is possible**
8 **without affecting hedonic perception**

9

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21 **Abstract**

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

34 **Keywords:** sugar reduction; dairy products; children; reformulation.

35

36 **1. Introduction**

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

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

52 Sugar content of dairy products can be gradually reduced so that consumers get
53 used to lower sugar concentrations without noticing any differences (MacGregor &
54 Hashem, 2014). Implementation of this approach requires estimation of difference
55 thresholds, i.e. the reduction in added sugar concentration that causes a perceivable
56 change in 50% of consumers' (McCain, Kaliappan, & Drake, 2018). Despite advances
57 by the food industry in the field of sugar reduction (Moore, Sutton, & Hancock, 2020),
58 open information regarding implementation of sugar reduction strategies remains scarce.
59 Previous studies conducted with adult consumers have shown that sugar reductions of
60 20-30% may be achieved without compromising acceptance (Alcaire, Antúnez, Vidal,
61 Giménez & Ares, 2017; Hoppert et al., 2013; Li, Lopetcharat, & Drake, 2015; Lima, Ares
62 & Deliza, 2018; Oliveira et al., 2016). However, information about children's hedonic
63 sensitivity to sugar reduction in dairy products is limited. Only a few studies have been

64 published assessing sugar reduction in chocolate-flavored milk (Li, Lopetcharat, &
65 Drake, 2015; Li, Lopetcharat, Qiu, et al., 2015) and vanilla milk desserts (Velázquez,
66 Vidal, Varela, & Ares, 2020).

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

70

71 **2. Materials and Methods**

72

73 *2.1 Samples*

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

83

84 *2.1.1 Vanilla milk desserts*

85 All samples were prepared using a base formulation containing UHT whole milk
86 (3.2% fat and 4.7% carbohydrates) (Conaprole, Uruguay), 4.3% w/w starch (Purity HPC,
87 Ingredion, Brazil), 0.4% v/w vanilla (Aryes, Jaraguá do Sul, Brazil), 0.1% w/w
88 polyphosphate and 0.02% w/w carrageenan (Ticaloid® 710H Stabilizer - Texture
89 Innovation Center, TIC GUMS, PA, USA). Sugar (Alcoholes del Uruguay S.A., Bella
90 Unión, Uruguay) concentration was varied as detailed in Table 1. Samples were
91 prepared using a Thermomix (Vorwerk Mexico S. de R.L. de C.V., Mexico City, Mexico).

92 Powdered ingredients were mixed with the whole milk and heated at 90°C under constant
93 stirring for 5 min. After heating process, the vanilla was added to the mixture and stirred
94 for 1 min. Desserts were placed in glass jars and stored for 24 h at 6-8°C prior to the
95 evaluation.

96

97 *2.1.2 Chocolate-flavored milk*

98 Chocolate-flavored milk was prepared using UHT whole milk, 1% w/w alkaline
99 cocoa powder (Aryes, Montevideo, Uruguay), 0.08% w/w carrageenan, 0.05% v/w
100 vanilla and varying concentrations of sugar (Table1). Samples were prepared using a
101 Thermomix by adding the powdered ingredients to whole milk, previously heated at 70°C
102 for 3 min, and dispersed for 1min. The mixture was kept at 70°C for 4 min under constant
103 stirring. Then, vanilla was added to the mixture and stirred for 1 min. Finally, the samples
104 were cooled down to 20°C in ice water and placed in glass jars. Samples were stored for
105 24 h at 6-8°C until their evaluation.

106

107 *2.1.3 Vanilla yogurt*

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

112

113 *2.2 Participants*

114 A total of 126 children (8 to 13 years old (M=10.6 years old, SD=1.3), 52% girls)
115 were recruited from three institutions in Montevideo, Uruguay (one school and two social
116 clubs). For every child, one of the parents signed an informed consent form to allow their
117 children to participate in the study, whereas children provided informed assent to
118 participate through the software used for data collection. It was explained that their
119 participation was voluntary and that they could withdraw at any time. Ethical approval

120 was obtained from the Ethics Committee of the School of Chemistry of Universidad de
121 la República (Protocol No 101900-000090-19).

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

128

129 *2.3. Experimental procedure*

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

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

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

146 Samples were presented in plastics cups, coded with 3-digit random numbers at
147 8°C. For evaluation of milk desserts, children received a plastic spoon for each of the

148 samples. Still mineral water was used as palate cleaner. A text was added to the test to
149 remind children of rinsing their mouth after assessing each of the samples. Children
150 completed the test at their own pace, as no specific timing was set.

151

152 *2.3.1. Task Familiarization*

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

159

160 *2.3.2. Sample familiarization*

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

167

168 *2.3.3. Sample tasting*

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

175

176 **2.3 Data analysis**

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

186

187

188 **3. Results and Discussion**

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

196 Table 2 shows the d' estimates and their corresponding standard errors, which
197 measure the sensory difference between each of the sugar reduced samples and the
198 reference sample (without sugar reduction) (Lee & O'Mahony, 2004). As expected, d'
199 values were not significantly different from 0 for the smallest added sugar reductions for
200 the three product categories. For vanilla milk desserts, d' was significantly different from
201 0 when added sugar reduction was 27.1% or higher. This suggest that sugar reductions
202 up to approximately 25% would be possible without significantly affecting children's
203 hedonic perception. Similar results were obtained for chocolate-flavored milk and vanilla

204 yogurt. As shown in Table 2, d' values were significantly different from 0 when sugar
205 reduction was 34.4% or higher, suggesting that in these products added sugar can be
206 reduced up to 34% without affecting children's hedonic perception.

207 Results from the present work are similar to those reported by other authors when
208 evaluating adults and children's hedonic sensitivity to sugar reduction in different food
209 matrices, including dairy products (Alcaire et al., 2017; Chang & Chiou, 2006; Chollet,
210 Gille, Schmid, Walther, & Piccinali, 2013; Hoppert et al., 2013; Lima et al., 2018; Oliveira
211 et al., 2016; Pineli et al., 2016; Velázquez et al., 2020). Although children have been
212 reported to have a heightened preference for sugar as compared to adults (Zandstra &
213 De Graaf, 1998), evidence from this work suggests that the added sugar content of dairy
214 products targeted at children can be reduced up to 25-30% without affecting
215 acceptability.

216 Interestingly, hedonic sensitivity to sugar reduction was largely similar across the
217 three product categories. As shown in Table 2, children were slightly less tolerant to
218 sugar reduction in vanilla milk desserts as compared to chocolate-flavored milk and
219 vanilla yogurt. This difference could be explained by changes in thickness and
220 creaminess caused by sugar reduction in milk desserts (Alcaire et al., 2017; Velázquez
221 et al., 2020), which might not be so relevant in yogurt and flavored milk.

222 Until now, one of the most popular strategies to reduce sugar content in dairy
223 products has been the use of non-nutritive sweeteners to maintain sweet taste (Moore
224 et al., 2020). Results from the present work suggest that relevant straight sugar
225 reductions, without compensating with extra sweeteners, could be rapidly achieved in
226 products targeted at children. Apart from its contribution to lowering sugar intake, gradual
227 sugar reduction in dairy products could reduce children exposure to sweet taste,
228 contributing to reducing their sweetness preferences (Mennella & Bobowski, 2015;
229 Nicklaus & Remy, 2013).

230

231

232 **Conclusions**

233 Results from the present work suggest that added-sugar can be reduced up to
234 25% in dairy products targeted at children without affecting their hedonic perception. This
235 information is highly valuable for sensory scientists and food technologists and confirms
236 that sugar-reduction strategies can be swiftly implemented in the dairy industry without
237 significant risks of affecting market share. In this sense, these results stress the lack of
238 justification of the slow response of some dairy industries worldwide to reducing the
239 sugar content and sweet taste of their products targeted at children.

240

241

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248

249

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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 (n=54)	10.0	50	0.174	0.227	0.280
	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 (n=64)	10.0	63	0.188	0.216	0.853
	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 (n=76)	10.0	71	0.219	0.194	0.165
	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.