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Sweetness Assessment of an Infant Formula Milk Powder with Added Sucralose

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Abstract Sucralose has been detected in breast milk. Although never experimentally proven, this finding has led some authors to state that the presence of this sweetener might intensify the natural sweetness of milk thus favoring infants to have a higher preference for sweet foods. Through Projective Mapping method, the present study carried out a sensory characterization of 10 infant formula milk powders (IFMP). A sample without sensory defects and with a lactose content like that of breast milk was selected. 15 sensory judges performed an Alternative Forced Choice (AFC-2) test between the sample without added sweetener and 9 samples with added sucralose in concentrations between 0.000096 and 0.016 g/L. The results yield experimental evidence that shows there is very low probability that the reported sucralose concentration in breast milk can make it be perceived as sweeter.

Keywords: *infant formula milk powder, sucralose, non-caloric sweeteners, sweetness*

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1. Introduction

Maternal breastfeeding is the best option to provide infants a perfect food to achieve their optimal health, development, and growth. On this matter, the World Health Organization (WHO) promotes, as a global public health recommendation, that babies must be exclusively breastfed during their first six months of life. From that on, they should continue with breastfeeding while receiving nutritionally adequate and safe complementary foods until 2 years or more [1].

It is well-known that different flavors derived from the mother's diet can be perceived in breast milk, such as: vanilla [2], carrot [3] or garlic [4], among others which are combined with the regular milk sweetness [5]. Therefore, breast milk acts as a provider of both, nutrients, and early sensory experiences for the infant [6].

Nowadays in which calorie and sugar intake is higher than the recommended [7,8], the replacement of sugars by non-caloric sweeteners (NCS), becomes an attractive option to reduce both, the total calorie intake and that of free sugars.

In this context, the presence of three NCS in breast milk has been described: acesulfame-K, saccharine, and sucralose [9,10]. They are about 200, 300 and 600 times sweeter than sucrose, respectively; hence the quantity of NCS used in foods and beverages is scarce. This is the reason why the quantity of NCS that is absorbed and reaches systemic circulation is also very low [11].

The NCS concentrations reported in breast milk showed that only sucralose -with a concentration of 0.034 μg/mL- would surpass the sweetness detection threshold. Considering that early feeding experiences are one of the main determinant factors of children's choices and subsequent food consumption [12], though never experimentally demonstrated, it has been speculated that sucralose might intensify the natural sweetness of breast milk, thus impacting on future infant dietary preferences (with a predilection for sweet foods) with the concomitant positive association with overweight and obesity [9,10].

Beyond the plausibility of these hypotheses, nobody has still proven if the sucralose concentration reported in breast milk could effectively modify the sweetness perception that is characteristic of breast milk, which is basically provided by its high lactose content.

Given the difficulty to use breast milk for the sensory evaluations, a sensory characterization of several infant formula milk powders (IFMP) was planned to find the one with a sensory profile and chemical composition closest to that of breast milk. IFMPs are substitutes of breast milk for those babies with mothers that cannot breastfeed or choose not to do it [13]. Various authors have suggested that breast milk has a higher acceptance by babies than infant formulas because of the difference in their sensory characteristics as well as in their volatile composition. It has been found that the volatile fraction of human breast milk was characterized by aldehydes, terpenes, alcohols, and ketones, whereas carbonyl compounds such as ketones and aldehydes, represented the main volatile compounds in infant formulas [14].

The sensory profile of a food product is traditionally obtained by a descriptive analysis performed by a panel of trained judges [15]. This methodology provides very accurate and reproducible results. However, it has the disadvantage of consuming significant amounts of time as well as being relatively costly [16]. During the last years several methodologies of quick sensory characterization have been developed. These methods have the advantage of reducing the necessary time to obtain results and associated costs as well. Moreover, they can be performed by subjects without previous training such as consumers or semi-trained judges [17].

One of the quick descriptive methodologies to study the sensory perception of foods, was developed by [18], and was named Projective Mapping (PM). In this methodology, subjects are required to test a group of samples and then, using their own criteria, distribute them on a map according to differences and similarities. Each assessor is responsible to choose those characteristics that, according to his/her own criteria, determine differences and similarities among the samples and their relative importance, therefore making this methodology to be very flexible and spontaneous. As this technique by itself does not provide descriptive information of the samples, after placing samples on the map, each of the assessors is required to write a brief description of each sample or group of samples. This is known as ultra,flash,profiling [19,20]. The information provided by this complement to the technique, can allow to identify the origin of the perceived differences among the samples. PM is one of the most popular holistic methods, with an emerging number of studies as well as applications in the last years upon different products [21,22,23].

For the above mentioned, the aims of the present study are to obtain a sensory characterization of IFMP through a PM in order to compare its sensory profile with that of breast milk, and to find the sucralose concentration capable of modifying the sweetness perception of an IFMP with a sensory profile as similar as possible to mature breast milk.

2. Materials and Methods

2.1. Study 1: Sensory characterization of infant formulas.

2.1.1. Samples

A sample of human milk (S1) and 10 canned IFMPs for babies between 0 to 6 months (S2 to S11) were assessed. Human milk sample was provided by the Human Breast Milk Bank of Centro Hospitalario Pereira Rossell (Montevideo, Uruguay) and consisted of a pool of mature human milks with an acidity of 5° Dornic and a lactose content of 7.7%. IFMPs were purchased in local marketplaces of Uruguay and Argentina. The IFMPs indicated a lactose content between 7.0 and 8.5 g/100 mL, a protein content between 1.2 and 1.6 g/100 mL, a total fat content between 3.1 and 3.7 g/100 mL and a saturated fat content between 0.7 and 1.5 g/100 mL of reconstituted powder. All IFMPs had in common the following ingredients: milk serum, partially hydrolyzed proteins of milk serum, skim milk/whole milk; lactose, maltodextrin, canola oil, galacto-oligosaccharides, sodium l-ascorbate, myo inositol, DL-alpha tocopherol, pyridoxine chlorhydrate, biotin, cholecalciferol, cyanocobalamin, taurine, choline, D-pantothenate and thiamine.

IFMPs were reconstituted in accordance with [24] guideline, with 150 g of powder in 1000 mL of filtered water at room temperature. Before the sensory analysis, the reconstituted IFMPs were left to balance during 45 minutes in agitation at room temperature.

2.1.2. Sensory Evaluation

IFMP sensory profile was obtained by Projective Mapping Methodology [18] with a panel of 12 sensory judges. 6 of them were members of the permanent panel of Milk Powder Quality Control of the School of Chemistry (Universidad de la República, Uruguay) and the other 6 had previously participated in several descriptive evaluation tasks but were not trained upon the specific product. 11 samples were assessed according to [25], in a single session in a normalized sensory evaluation room.

The evaluation was carried out individually. Each panelist received every sample. Samples were codified with random three-digit numbers and the panelist was asked to test them trying to recall the sensory characteristics of each one. In addition, each panelist was provided with still mineral water to drink in between the samples as an eraser. Then, the panelist was asked to place the samples on an A3 sheet according to his/her criteria. The only rule the panelist had to follow was: “The samples placed closer to each other, will indicate similarities among them and those placed farther will indicate differences” [26].

Once the samples were placed on the sheet, panelists had to write their codes and to place a note aside with no more than 5 sensory attributes or comments to describe them [23].

2.1.3. Data Analysis

The Projective Mapping data were analyzed as follows: the coordinates (x, y) of the position in the A3 sheet of each judge´s sample was measured in centimeters, considering the lower left edge as the coordinate’s origin (0.0).

All the attributes or comments generated were analyzed. Those terms used to describe one sample or group of samples, that have the same meaning (synonyms), were grouped using a Spanish language dictionary as a help. This stage was carried out by three researchers independently, determining the final descriptors together by triangulation. The frequency of each term´s mention was determined by counting the number of mentions of the same term for each sample. The synonym mention frequency and that of repeated sensory attributes was combined and considered as a single variable in the data analysis.

A Multiple Factor Analysis (MFA) was carried out upon the table of coordinates and frequencies of the descriptive terms that were generated. The descriptive terms were considered as supplementary variables; therefore, they did not contribute to the conformation of MFA factors; they were only projected upon the results. The first two MFA dimensions were selected to represent the sensory space determined by the assessed samples. The statistical analyses were carried out using XLStat 2020 (Addinsoft, NY) software.

2.2. Study 2: Sweetness perception in an IFMP with added sucralose.

The IFMP selected in study 1, was reconstituted according to [24] guideline, with 150 g of powder in 1000 mL of filtered water, at room temperature. Different amounts of sucralose, between 0.000096 and 0.016 g/L, (see Table 1) were added to obtain 9 samples with different sucralose concentrations. Before the sensory analysis, the reconstituted IFMPs were left to balance during 45 minutes in agitation, at room temperature.

Table 1. Sucralose Concentration Added To The Selected Infant Formula Milk Powder And Number Of Responses In Favor Of The Samples With Added Sucralose.

Sample	Sucralose concentration (g/L)	Number of responses in favor of the sample with added sucralose	Probability level
A	0.016	30 in 30	< 0.0001
B	0.008	28 in 30	< 0.0001
C	0.004	30 in 30	< 0.0001
D	0.002	24 in 30	0.001
E	0.001	18 in 30	0.181
F	0.0005	18 in 30	0.181
G	0.00025	16 in 30	0.428
H	0.00016	14 in 30	0.708
I	0.000096	12 in 30	0.900

15 trained sensory judges and members of the sensory panel of the School of Chemistry (Universidad de la República, Uruguay) received 9 pairs of samples. Each pair consisted of the control IFMP (without added sucralose) and one of the samples with added sucralose in different concentrations. All samples were presented in odor-free plastic glasses labeled with 3-digit random codes. The presentation order of each sample within each pair was random as well as the presentation order of pairs. Still mineral water was available for rinsing. Testing took place in a sensory laboratory in standard sensory booths that were designed in accordance with [25]. Test was carried out by duplicate. In each pair, according to Alternative Forced Choice (AFC-2) methodology, the assessors had to respond the following question ¿what is the sweetest sample? In AFC-2 test, 2 products are presented to each assessor. The assessors must tell which product has the highest intensity for a particular characteristic. P-value and power for these tests are obtained using the binomial distribution [27].

3. Results and Discussion

3.1. Study 1: Sensory characterization of infant formulas

The first MF dimensions explained the 48% of the variability found in the data. According to Figure. 1, the first dimension was positively correlated with "white", "fresh" and "metallic", and negatively correlated with "yellow", "heterogeneous", "oil flavor" and "smooth flavor". These descriptors were the responsible of differentiating breast milk (S1) from the infant formulas (S2 to S11). The second dimension was positively correlated with "homogeneous", "little sweet", "aged" and "rancid", characterizing the samples S3, S6 and S11, whereas the second dimension was negatively related to the attribute "sweet", characterizing mainly the S10 sample.

The results showed the existence of great differences regarding the sensory characteristics of different products in the market. Clearly differentiating to one another, breast milk was characterized by being yellow, heterogeneous, with a smooth flavor and an oil flavor, whereas the IFMPs were found with other flavors such as metallic, flour flavor and fresh flavor. These results coincide with those of other authors, who reported that, related to heat treatment, IFMPs differed from breast milk as they contained some volatile compounds such as methional, 2-furfural and sulfides, which were not present in breastmilk. On the other hand, breast milk had a higher variety of terpenes, aldehydes, and alcohols [14].

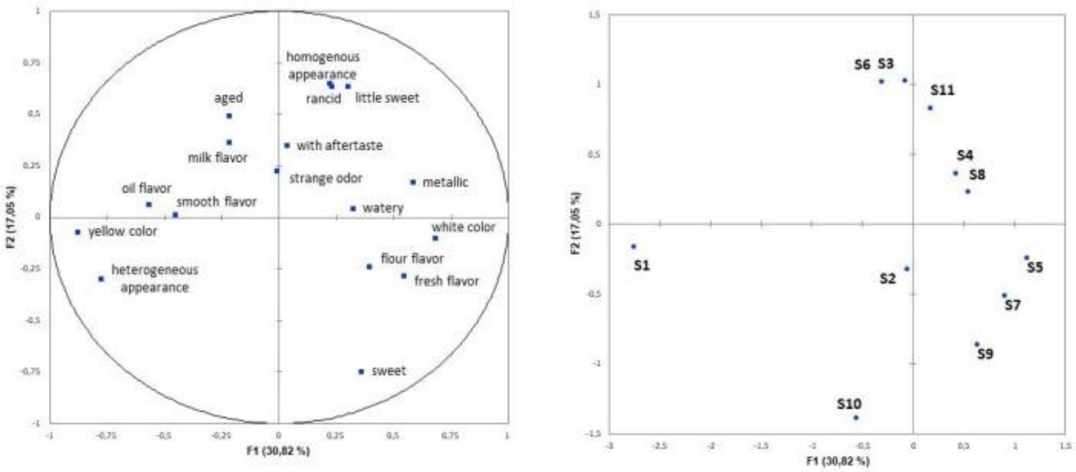

Figure 1. Sample configuration in the first and second dimensions of the Multiple Factor Analysis (MFA) performed on Projective Mapping data.

In IFMPs, sterilization or dehydration is necessary to provide an appropriate bacteriological safety and extend its lifetime [13]. However, these processes can affect the sensory characteristics. For instance, the infant formulas combine a series of factors that favor the non-enzymatic-food browning such as: high quantities of lactose and lysine, relatively high temperatures and longtime of storage [28].

Defective flavors such as rancid and aged were found in samples S3, S6 and S11, indicating a lipid deterioration that may decrease the product's sensory and nutritional quality. The quality of milk-based powder foods can be deteriorated due to chemical reactions, such as lipid oxidation and Maillard reactions [29]. Some authors have reported that even little differences in milk composition that are used for powder production and even little adjustments in its processing, may significantly affect the final product's stability [30]. The addition of both polyunsaturated lipids that are not normally found in milk and iron salts, are able to increase free radicals' generation, especially in the presence of ascorbate as another potential additive, which drastically increases the product's lability [31]. It is known that a higher temperature during the storage of powder foods also quickens quality deterioration, as, in most of the cases, the physical transformations as well as the chemical reactions, increase its deterioration speed when temperature increases [32]. It can be deducted that although being within the commercialization period declared by manufacturers, some of the infant formula milk powders used in the present study presented a quality deterioration. The later should be confirmed through physicochemical analysis to determine the oxidation of lipids that are present in these products.

A survey among mothers who administered IFMP to their babies, showed that they rarely taste the product [33]. Reference [34] concluded that flavor is the most important attribute and that there is no consumer who completely ignores it. But in this case, the consumer is a baby who cannot decide, and it is known that mothers will stop the product's administration only if the baby has digestive symptoms. Since we found IFMP with signs of lipid oxidation, it would be worth to have a detailed analysis of its nutritional quality.

As a result of this first study, S2 was selected to carry out the second study, considering that it presented no defective flavors and had a similar sweetness to that of breast milk. Moreover, the lactose content declared (7.7%) was in the range of mature breast milk (6.7 to 7.8%) [35].

Considering both, its sensory profile, and its chemical composition, S2 is the closest model to breast milk reported up to date for estimating the sucralose concentration capable of modifying milks´ sweetness perception.

3.2. Study 2: Sweetness perception in an IFMP with added sucralose

When NCS were reported in breast milk, it was suggested that their presence might modify the natural milk sweetness, favoring infants to grow with a particular preference for sweet flavors. It was also speculated that this early exposure to NCS might influence the child's future metabolism and health [10,36].

It is important to consider that these hypotheses emerged from studies that were thought to assess the pharmacokinetics of different NCS in breast milk. Said studies didn't investigate if milk sweetness was really modified by the presence of NCS at the reported concentrations.

For supporting or ruling out these hypotheses it is essential to assess what NCS concentration can increase sweetness in a milk with similar characteristics to that of breast milk; particularly for the case of sucralose, being the only NCS reported in breast milk, whose sweetness detection threshold has been surpassed. This assessment will provide evidence upon the plausibility (or not) of the reported sucralose concentrations being able to alter breast milk organoleptic characteristics.

Table 1 shows the number of responses in favor of the sample with added sucralose; that is the number of judges that considered the sample with added sucralose to be sweeter than the control sample.

It was found that samples with 0.002g/L or higher content of added sucralose, were perceived as significantly sweeter than that of the sample without sucralose ($p<0.05$).

Considering that the highest sucralose concentration in breast milk reported in [36] was 0.04 µg/mL (0.00004 g/L) and that our study demonstrates the need for a concentration 50 times higher to perceive as sweeter an IFMP with similar characteristics to that of breast milk, it is highly unlikely that the sucralose concentration reported in breast milk could intensify its sweetness.

This study has some limitations. Firstly, we had to find an infant formula with similar characteristics to that of breast milk -both chemical and sensory- considering the impossibility to directly perform the sensory analysis in human milk. Even though the composition of infant formulas is industrially modified adjusting the quantities of nutrients to make them comparable to human milk [37], both matrixes are not the same. Secondly, it also must be considered that babies´ sweetness perception might be higher than that of adults because they have a higher number of fungiform papillae [38]. Therefore, we could be overestimating the necessary sucralose concentration for a baby to perceive breast milk as sweeter.

Finally, the main strength of our study lies in analyzing for the first time the ability of sucralose to modify sweetness in a milk matrix close to that of breast milk. This article provides higher quality evidence compared to previous hypotheses that were merely speculative.

As future lines of investigation, it would be useful to replicate this analysis for the other two NCS that were described in breast milk: saccharine and acesulfame-k. Although their reported concentrations do not surpass the sweetness detection threshold, it would be interesting to know which concentrations might lead the milk to be perceived as sweeter. Finally, after this first approximation, it is imperative to perform this sensory analysis directly in human milk (ideally in colostrum, transition milk and mature milk) which is the most appropriate research model.

4. Conclusions

This study provides experimental evidence that shows that is highly unlikely that sucralose concentrations reported in breast milk could led an infant to perceive it as sweeter.

Statement of Competing Interests

B.M. Cavagnari has received fees as a speaker from Heartland and from the International Sweeteners Association, being a member of their scientific advisory panel. He is also responsible for the scientific area of Nutricia Bagó in Argentina. These activities have no relation with this article.

List of Abbreviations

(IFMP) Infant Formula Milk Powders
(AFC-2) Alternative Forced Choice
(WHO) World Health Organization
(NCS) Non-Caloric Sweeteners
(PM) Projective Mapping
(MFA) Multiple Factor Analysis

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