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Sensory Quality and Acceptability in Mesquite Flour Complemented- and Mineral- Fortified Cookies Sensory Evaluation In Fortified Cookies

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***Abstract*— This study examined the sensory properties in cookies with varying levels of Fe and Zn in prototipes of cookies in order to understand the impact of fortification. Understanding the impact of fortification can be used in without adversely affecting the sensory properties.**

These results suggest that a Fe and Zn fortification is possible in (orange and chocolate taste) cookies, made with wheat and mesquite flour and oat without significant impact to sensory perceptions.

Practical applications:

It is known that iron, calcium and zinc are regarded as micro nutrients critical minerals because they are usually present in substantially lower levels than those recommended, Local nutritional studies are in agreement with these assertions. In order to satisfy people's daily nutrient requirements, mineral is added to some food products. However, iron-fortified foodstuffs are characterized by dark colors, metallic taste, and low consumer acceptance.

This work was chosen to develop cookies because these are a fortification vehicle with a high level of acceptability, mainly for children, due to their attractive features. Furthermore, because of their long shelf life, cookies can be produced and distributed at a large scale.

In this context, it seems interesting to propose that Government's social nourishment programs include foodstuffs exhibiting nutritional characteristics that offset the deficiencies detected and sensory attributes which make them eligible.

***Index Terms* — sensory evaluation, cookies, mesquite flour, minerals.**

I. Introduction

Designing a new food product with specific purposes involves tests in which sensory and statistical methods play an important role. Current trends in consumers behavior causes food industry to try to satisfy their requirements, especially if a nutrition deficiency is to be corrected.

In Latin America, school children usually eat snack-type foods of low protein quality, but rich in saturated fats, sugars and sodium [1]. This, coupled with a sedentary behavior, brings about an increase in infant obesity indices, among other health problems [2].

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On the other hand, it is known that iron, calcium and zinc are regarded as critical minerals because they are usually present in substantially lower levels than those recommended [3; 4]. Local nutritional studies conducted by Macías [5; 6] are in agreement with these assertions. In order to satisfy people's daily nutrient requirements, iron is added to some food products. However, iron-fortified foodstuffs are characterized by dark colors, metallic taste, and low consumer acceptance [7]. Hence, it becomes important to know the changes that occur in the sensory features of food as a result of fortification, as well as its effect on the final cost of the fortified foodstuff [8].

In this context, it seems interesting to propose that Government's social nourishment programs include foodstuffs exhibiting nutritional characteristics that offset the deficiencies detected and sensory attributes which make them eligible.

The use of flour mixtures (taking advantage of the amino-acidic complementation between wheat and alternative flours) for manufacturing baked goods has some nutritional advantages. In addition to providing nutritional benefits, it creates a diversified food supply and makes it possible to utilize certain regional raw materials. Thus, baked products have been developed, with added mesquite, soybean and rice flour, with the purpose of incorporating nutrients [9, 10, 11, 12]. A number of research papers dealing with incorporating mesquite flour to baked products in order to enhance the protein quality of wheat flour can be found in the literature [13, 14]. In addition, other researchers state that mesquite flour provides significant amounts of calcium [15]. On the other hand, fortifying massive consumption foods is one of the most widespread cost-benefit strategies used to prevent populations' mineral deficiencies [16, 17].

Cookies are a fortification vehicle with a high level of acceptability, mainly for children, due to their attractive features. Furthermore, because of their long shelf life, cookies can be produced and distributed at a large scale. Even so, children attending school cafeterias say they need to eat a variety of tasty foods [18]. However, the sensory quality and acceptability of fortified formulations intended for social nourishment programs have not been studied. This affects the consumption and success of these developments. Therefore, when stating the key sensory attributes of this product, two factors should be taken into account: (a) determining the high variability sensory indices, and (b) identifying the sensory features that lead the consumers to hedonic responses [19].

II. MATERIALS AND METHODS

A. Materials

Favorita brand 0000 (HT) commercial wheat flour, Quaker brand (A) commercial oat flour, and mesquite (Prosopis alba) flour (HA) from ground pods collected in various locations in Santiago del Estero, Argentina, were utilized.
As the fortifying core, a 0.2% mixture of ferrous fumarate (33% Fe) and zinc gluconate (12% Zn) was utilized, while 0.35% citrus orange essence and fresh orange essence, together with 0.24% chocolate essence, were used as flavorings.

Upon preliminary formulation, manufacturing, and sensory evaluation tests conducted by trained judges, four cookie prototypes were prepared/made by combining the flours in an 80HT:10HA:10A proportion, with added flavorings and fortifiers (f). As a result of flavoring with orange (N) and chocolate (C), four different cookies were obtained, hereinafter: N, Nf, C, and Cf.

The cookies were prepared at Nutrisantiago manufacturing plant by mechanically kneading all the ingredients simultaneously according to the formulation shown in Table 1. Water, sugar and oil were added by means of automatic dosing hoppers. The mixture of wheat, oat and mesquite flours, as well as the other components such as baking soda, lecithin, coloring agents, flavorings and honey, were added manually.

The resulting dough was laminated and died into 4cm-diameter pieces that were baked in a continuous baking oven at 190°C for 12 minutes. The cookies were cooled at room temperature and packed in flowpack pouch type bags. They were then stored in a MJ2-AR conditioning chamber, model MJ-250-II, provided with an automatic temperature (15°C) and humidity (70%) regulator.

Total mineral content of calcium (Ca), iron (Fe) and zinc (Zn) in the samples was determined by atomic absorption spectroscopy, upon humid mineralization [20] with a 50:50 mixture of $HNO3$ and $HClO4$. Three replicates of the determinations were made.

Table 1. Components of the fortified-core cookies.

	Chocolate cookie recipe		Orange cookie recipe	
Ingredients	Quantity [kg]	**%**	**Quantity [kg]**	**%**
Crystal Sugar	15	17.67	15	18.29
Sunflower oil of high oleic acid content (HOSO)	10	11.78	10	12.19
Honey	1	1.18	0.5	0.61
Soybean lecithin	0.15	0.18	0.15	0.18
Chocolate esssence	0.2	0.24	-	-
Caramel coloring	1	1.18	-	-
Cocoa powder	1.5	1.77	-	-
TQ Nutras antioxidant	0.02	0.02	0.02	0.02
Sodium bicarbonate (baking soda)	0.25	0.29	0.25	0.30
Ammonium bicarbonate	0.5	0.59	0.5	0.61
Salt	0.125	0.15	0.125	0.15
Water	5	5.89	5	6.10
Premix LG1 Letritas	0.1675	0.20	0.17	0.21
Wheat flour (000)	40	47.11	40	48.78
Oats	5	5.89	5	6.10
Mesquite flour	5	5.89	5	6.10
Citrus orange essence	-	-	0.165	0.20
Fresh orange essence	-	-	0.125	0.15

A. Quantitative descriptive analysis

This descriptive analysis was carried out according to the method developed by Stone [21] which involves the search for descriptors and the definitive tests to measure the sensory features of the product.

The descriptors search tests was performed on various manufactured as well as commercial cookies. In turn, the definitive tests to measure the intensity of attributes were carried out on cookies (Cf and Nf) from one manufacturing batch.

Eight trained judges were selected to carry out the programmed experiences on samples served on individual plates. The panelists expressed their perceptions about the various cookies along six sessions, with the aid of a panel leader and a standard guiding grid stated by Argentina's IRAM Standard 20001 [22].

In selecting the descriptors, the judges mainly considered the optimization of acceptability and the sensory quality.

Those descriptors of similar meaning as well as those with a frequency less than 40% [23] were eliminated.

To measure attribute intensity, 10 cm scales anchored at its ends were used. The horizontal line exceeds the limit of 10 cm so as to encourage the evaluator to use it to classify those samples that require doing so. Four repetitions were carried out. Those descriptors showing differences were measured again during four additional sessions, after the panel was re-trained.

Two-factor analysis of variance was used to test the resulting data. The factors were sample and taster.

B. Sensory quality analysis

To assess the sensory quality of the cookies, an ordinal ranking test was conducted with 11 selected tasters, according to Argentine Standard 20002 [24, 25]. A ranking scale which is frequently used in the sensory evaluation of foodstuffs was employed because it allows to grade various quality values when trained judges are involved [25]. The American Association of Cereal Chemists (1962) assigns importance to the quality factors of breads and cookies, and rates their general appearance, crust color, grain, texture, flavor and taste [19].

The cookies were served at room temperature on plastic plates codified with 3-digit random numbers. The samples were randomly presented to the tasters for evaluation. Mineral water was used as a neutralizer, and successive evaluations were made at 2-3 minute intervals.

The judges performed a sensory evaluation of the cookies as a whole and also considering attributes such as color, odor, taste, consistency (manual hardness) and crunchiness, using a 5-level ordinal qualitative scale: Very Good, Good, Fair, Bad, and Very Bad. For statistical processing purposes, these were codified with numerical values ranging from 5 to 1, respectively. The resulting data were analyzed by means of a logistic regression model that assesses the influence of the attributes on the global opinion of the judges.

C. Evaluation by consumers

An acceptability test was carried out to determine whether the sensory features of the prototype samples were accepted by the target consumers. Since the cookies were developed and manufactured for school children in Government's social nourishment programs, this test was conducted in General Basic Education schools of Santiago del Estero, with a total of 102 children between 9 and 11 years old: 52 girls and 50 boys. Additionally, the cookies were compared with equivalent commercial products in order to establish their potential introduction into the local market [18].

The six samples were presented in a balanced order fashion, with each sample being served the same number of times in each order of presentation. The cookies were presented in disposable trays, coded with 3-digit numbers randomly chosen. Each participant received the samples and one individual evaluation grid. A 1 to 10 point scale for low-income populations was used for evaluation purposes [18]. The attributes measured were appearance, consistency (manual hardness) and global acceptance. The responses ranged from "dislike extremely" (1) to "like extremely" (10). A level of significance of 5% was adopted. When significant differences were found, Fisher's minimum significant difference (MSD) method was used.

III. RESULTS AND DISCUSSION

A. Minerals

Total Fe, Zn and Ca contents in the cookies are shown in Table 2.

As far as Fe and Zn are concerned, the values obtained exceed the Recommended Daily Intake (RDI), and the Nf and Cf cookies can thus be regarded as fortified food in accordance with Article 1363 of the Argentine Food Code (AFC). The RDI for both Fe (9 mg/day) and Zn (5.6 mg/day) was taken as a reference. In the AFC, these values are expressed in terms of a moderate bioavailability for zinc and 10% for Fe.

If the Ca contents of prototypes Cf (89.3 mg/100 g of cookie) and N (98.9 mg/100 g of cookie) are compared to those of equivalent commercial products usually consumed as school snacks (e.g. Oreo cookies and Ahoy! Chips, among others), which contain approximately 2.77mg/100g of product, one can infer the importance of the product developed specifically for school children, whose Ca requirements are high [26]. However, when comparing Ca contents of the new formulations with those of other cookies made with fermented legumes and cereals, developed by Granito et al. [26], with a Ca content of 250mg/100g of product, it becomes clear that the former values are lower. On the other hand, breads manufactured with mesquite flour showed a Ca content of 85.5mg/100 g of product [27]. It should be pointed out, however, that these formulations contained low-fat milk.

Table 2. Total Fe, Zn and Ca content in the cookies.

Prototypes	Fe		Ca		Zn	
	X mg%	DS	X mg%	DS	X mg%	DS
N	3,2	0,1	98,9	2,9	1	0,1
Nf	16,2	1,2	93,2	6	8,3	0,3
C	6	0,3	98,1	7,8	1,5	0,1
Cf	17,5	1,2	89,3	4,4	9	0,6

B. Sensory evaluation by trained judges

Quantitative descriptive analysis

From the tasters' perceptions, a list of 20 descriptors was developed. In order to reduce the number of descriptors, those with a similar meaning (earthy, powdery, brittle, crunchy) and those used with a frequency lower than 40% were eliminated. Given the purpose of the study, 17 and 16 descriptors were selected to describe the quality of Nf and Cf, respectively. Since the frequency distribution of all the observations follows the normal distribution for each descriptor, the sample mean was used to characterize the descriptors. The results of the quantitative descriptive analysis for cookies Nf and Cf are shown in Figure 1.

Nf and Cf are significantly different ($p<0.05$) with regard to the descriptors texture (manual and oral hardness), astringent taste and flavor due to the essence used.

The stronger the smell of the flavoring essence used, the lower the perception of the mesquite-pod smell by the evaluators; i.e. the mesquite-pod smell is best masked when orange essence is used.

As to chocolate flavor, the judges perceived it more intensely than they did orange flavor. It was also noted that astringent flavor is less perceived when the flavoring essence is more intense, which could be attributed to the fact that chocolate flavoring better masks the astringent flavor of mesquite flour. Sweetness was higher in cookies Cf (5.94 ± 0.69) than in Nf (5.42 ± 0.40) although both cookies had the same sugar content. The presence of chocolate flavor and smell in Cf may have influenced the increased sweetness perception.

The attributes and descriptors herein determined are useful, firstly, in carrying out tests with consumers in order to explain their reasons for acceptance, rejection or preference in terms of the vocabulary that was generated and quantified. Secondly, upon correlating the ata of the least preferred cookies with those quantified by the judges, it becomes possible to make reformulations, taking into account those attributes which determine lower preference, in an attempt to optimize the product.

Evaluating the sensory quality of the cookies through categorical attributes shows that prototype (prob. = 0.028), color (prob. = 0.016), consistency in terms of manual hardness (prob. = 0.054), and taste (prob. = 0.0095) are the variables that significantly define the judges' global opinion. These results emphasize the importance of sensory evaluation when valuing the manufactured product. This coincides with the QDA since the results indicate significant differences ($p<0.05$) between Nf and Cf as to the descriptors hardness (manual and oral texture), astringent taste, and flavor due to the essence used.

The results of the ordinal categorization test are shown in Table 3.

The variables odor intensity (Nf 6.53 y Cf 6.21) and flavor intensity (Nf 4.11 y Cf 5.41) are directly proportional to the quality values given by the judges. This doesn't hold true for the parameters crunchiness and consistency, which exhibit an inverse relationship; i.e., the judges give those parameters a lower quality value when the prototypes are harder and crunchier.

When comparing the radial graphs for Nf and Cf cookies (Figure 1), the parameter color was excluded because it was not selected as a descriptor of Cf. With regards to Nf cookies, their measured color intensity (5.31) exceeds the ideal value of 5, which agrees with the quality evaluation performed by the judges, who give a lower quality value to Nf (2.88) than to Cf (3.33). Although the characteristic color of these formulations is usually related to the effects of temperature and baking time on the sugar, fat, protein and starch contents which cause the typical coloration of Maillard's reaction, in this particular case, it might be further attributed to mesquite flour which darkens the dough because of its own color. In the case of Cf cookies, the dark color of the additive masks the color conferred by mesquite flour. The higher the sugar content in the cookies, including non-reducing sugars [28], the darker the brown color that will develop on the surface.

The results obtained for the parameters crunchiness and manual hardness might be related to the type of fat used in the manufacturing process because those cookies containing oil in their formulation show greater hardness in their texture due to the lack of proper aeration, which, in turn, affects the plastic features of the dough and the final product (Jacob 2006). As stated earlier, high oleic acid sunflower oil (HOSO) was used in the manufacturing process (Table 1) in order to enhance the nutritional quality of the cookies and increase the supply of foodstuffs capable of improving the balance in the ω6/ω3 ratio, an objective sought in the diet of Western countries. The addition of HOSO had an effect on the texture of the cookies.

The general opinion of the trained judges is shown by Figure 2, where one can see that none of them graded any of the cookies as Bad (2) or Very bad (1).

The acceptability test (Table 4) shows satisfactory results although the fortified cookies of both flavors obtained global acceptance scores ranging between 7.4 and 9 (1-10 scale), which are lower than those given to commercial cookies. Furthermore, the target student population granted the cookies acceptability scores of 7 or higher as follows: 73% to N, 76% to Nf, 87% to C, and 89% to Cf.

It should be pointed out that the children identified the commercial cookies by their external appearance, which may have favored their general acceptance. This adds value to the prototypes tested because they received high scores in the attributes acceptability and appearance, although they were evaluated in this context.

It should also be noticed that the chocolate-flavored cookies were better qualified, in all three attributes, than the orange-flavored ones. However, no significant differences were found between the prototypes N and Nf or between C and Cf with regards to global acceptance. This could be an indication that fortification is not perceived; hence, it does not determine acceptability.

Consistency was the feature that the school children liked the least. By correlating the results of the three sensory tests carried out, it was found that manual hardness was given lower scores than those given to appearance in all of the cookies studied. Similarly, the judges assessed the quality of manual hardness as regular and gave scores above 5 (the ideal) when quantifying this descriptor. This may suggest that, based on the children's evaluations, hardness should be diminished in order to optimize quality.

Although the expected results for crunchiness were not achieved, this should not be regarded as something negative. In fact, when a crunchy product gains humidity, it loses crunchiness and it is, therefore, considered as spoiled or of low quality [29].

Table 3. Average score per parameter for the quality of orange and chocolate cookies with and without fortifier.

Parameters	N	Nf	C	Cf
Color	3.03	2.88	3.48	3.33
Odor (smell)	3.18	3.93	2.88	3.78
Manual hardness	3.33	3.33	3.33	3.00
Crunchiness	4.25	3.63	2.88	2.73
Flavor	3.63	2-88	3.50	3.00
General opinion	3.83	3.63	3.33	3.00

Table 4. Mean sensory variables for each formulation.

Prototypes	Mean values		
	Appearance	Manual hardness (consistency)	Global acceptance
N	8,2	7,5	7,5
Nf	7,8	7,3	7,4
Commercial vanilla	9,4	8	9,2
C	8,6	8,1	8,7
Cf	8,8	7,8	9,0
Commercial chocolate	9,3	8,5	9,3

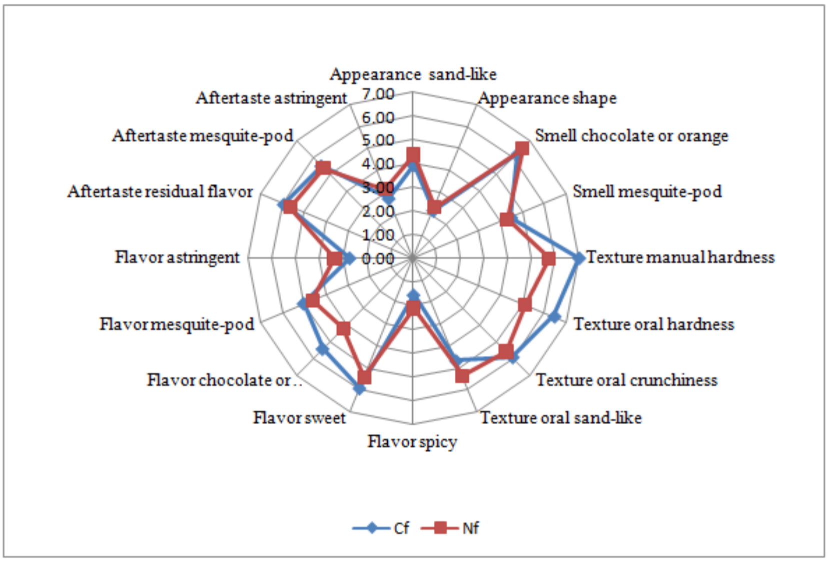

Figure 1. Comparative polar graphic for the sensory profiles of cookies Nf and Cf.

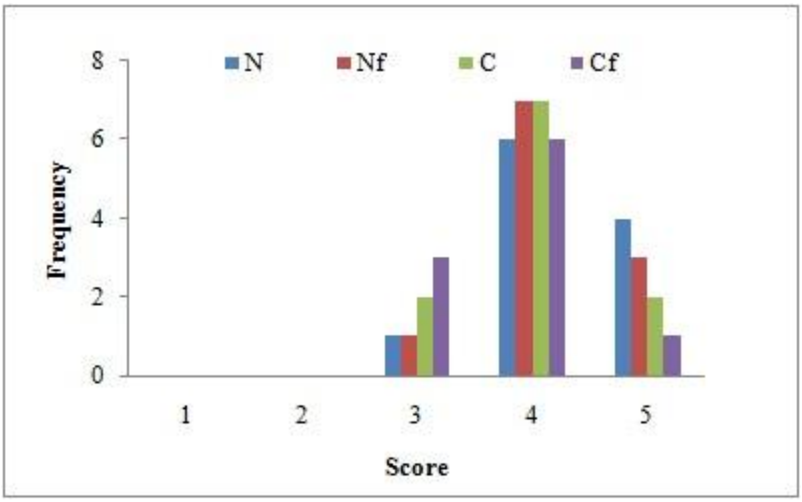

Figure 2: Frequency of the qualifications given to the cookies.

IV.CONCLUSIONS

The sensory profiles of Nf and Cf cookies were established.

The Nf and Cf prototypes were given satisfactory valuations as to their sensory quality.

The proposed formulation, in which wheat flour was partially replaced by mesquite and oat flour, was satisfactory accepted by the consumers.

The proposed prototypes with mineral fortification were well-valued and well-accepted by the consumers.

The sensory quality of the cookies was not modified by the addition of mineral fortifiers.

The effect of fortification on the sensory quality of the cookies was not detected by the trained judges; hence, it had no effect on the ranking of the product.

Chocolate flavoring considerably raised the global acceptability score by the school children population.

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