Artículo Original / Original Article

Consumer acceptability of a sweet bread nutritionally enriched through linear programming with broad bean, chia and amaranth flours

Aceptabilidad de un pan dulce enriquecido nutricionalmente mediante programación lineal con harinas de habas, chía y amaranto

ABSTRACT

The aim of this work was to improve sweet bread (R1) nutritionally by partially replacing the wheat flour with other non-traditional flours through linear programming. Chemical Score, lipid profile, microbiological quality and acceptability were determined. Both recipes, R2 and R3, were formulated according to the Dietary Guidelines for Americans; and R3 according to the maximum amounts of flours that impart negative sensory attributes, as well. The resulting proportions were: wheat/broad bean/chia/ amaranth flours 64/22/13/0 (R2) and 83/2/4/11 (R3). The obtained products presented adequate contributions of proteins and lipids, while fiber increased significantly. The Chemical Score increased from 46% (R1) to 95% (R2) and to 91% (R3) respectively, and the fatty acids ratio ω3: ω6 improved. R2 was not sensorially accepted while R3 presented high acceptability in adults and school-aged children. Recipe R3 could be included in school menus to improve children's nutritional status.
Keywords: bakery product; linear programming; nutrition improvement; sensory evaluation.

RESUMEN

El objetivo de este trabajo fue mejorar nutricionalmente un pan dulce (R1), reemplazando parcialmente la harina de trigo con otras harinas no tradicionales a través de la programación lineal. Se determinó la puntuación química, el perfil lipídico, la calidad microbiológica y la aceptabilidad. Ambas recetas enriquecidas nutricionalmente, R2 y R3, se formularon de acuerdo a pautas dietéticas estadounidenses; y para R3, además, se tuvieron en cuenta las cantidades máximas de harinas que imparten atributos sensoriales negativos. Las proporciones resultantes fueron harina de trigo/haba/chía/amaranto 64/22/13/0 (R2) y 83/2/4/11 (R3). Los productos obtenidos presentaron contenidos adecuados de proteínas y lípidos, mientras que la fibra aumentó significativamente. La puntuación química aumentó de 46% (R1) a 95% (R2) y a 91% (R3) respectivamente, y la relación de ácidos grasos ω3: ω6 mejoró. R2 no fue aceptado sensorialmente, mientras que R3 presentó alta aceptabilidad en adultos y niños en edad escolar. La receta

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R3 podría incluirse en los menús escolares para mejorar el estado nutricional de los niños.
Palabras claves: producto de panadería; programación lineal; mejora nutricional; evaluación sensorial.

INTRODUCTION

Bread has been a human food for ages and it contributes more than 50% of food energy[1].The consumption of bakery products is increasing largely due to growing urbanization, competitiveness of costs, consumption convenience and diversification[2]. However, wheat-based bakery products do not have enough essential nutrients[3]. Their nutrition improvement has been achieved by complementing them with other foods[4]. There are numerous works in which

bakery products and pastas have been nutritionally improved, combining wheat with other cereals and legumes[5,6].

Dietary intakes worldwide have changed rapidly[7]. Imbalanced proportions of macronutrients in the diet are linked to weight gain, and increased risk of chronic noncommunicable diseases such as hypertension, diabetes, cardiovascular diseases and some types of cancer[7]. In the Northwest of Argentina, a nutritional transition is taking place by replacing the traditional pattern of consumption with the incorporation of foods that increase the intake of sugars and refined grains[8]. Current nutrition trends emphasize the incorporation of whole grains into the diet to prevent some types of non-treatable diseases and maintain health.

Regional crops could be incorporated into food formulation to contribute with nutrition improvement strategies. The Northwest region of Argentina has grains, tubers and legumes with excellent nutritional quality, especially in terms of protein and lipids, fiber content, minerals, vitamins and antioxidant compounds[8,9]. Amaranthus (Amaranthus spp.) contains digestible proteins of high nutritional quality with essential amino acid content higher than that of common grains[10]. It is also a good source of fiber, rich in linoleic acid and it has a high content of calcium, iron and magnesium[9]. Broad beans (Vicia faba) are a source of proteins with high lysine content which makes them suitable to complement cereal proteins[5]. They also provide micronutrients such as folic acid, niacin, vitamin C, magnesium and potassium[5]. Chia seeds (Salvia spp.) are an important source of lipids, rich in polyunsaturated fatty acids, particularly omega-3 (50-57g/100g) and omega-6 (17-26g/100g)[2].

In food formulation, nutrition improvements can be achieved by finding raw materials whose nutrient contents are complementary. Linear programming is an effective and practical tool for calculating the proportions of raw materials necessary to formulate a food product[11].

In developing countries, school feeding programs are often used as a part of the social safety net. These programs often target food-insecure populations with high concentrations of families in low socioeconomic conditions[12]. In Argentina, there are school food assistance programs to improve feeding services in schools with vulnerable populations[13].

The aim of this work was to study the incorporation of broad beans, amaranth and chia flours in the formulation of a sweet bakery product to obtain a food product with an improved nutritional balance which is sensorial acceptable for children and adults using linear programming. This food product would contribute to the prevention of situations of nutritional risk, promote the consumption of regional crops and contribute to their revaluation.

MATERIAL AND METHODS
Raw materials

The control recipe (R1) formulated with wheat flour and potato was enriched with other flours. The ingredients for the nutritional enrichment of this bakery product (R1): amaranth, chia, broad bean and Andean potato, were selected based on their nutritional qualities, availability in the north of Argentina and also their inhabitants' cultural acceptance. They were provided by the CAUQUEVA cooperative (Maimara, Jujuy-Argentina) and regional producers. Wheat flour, butter, eggs, yeast, milk, sugar and vanilla essence were purchased in local stores.

Amaranth (Amaranthus), chia (Salvia hispánica L.) and broad beans (Vicia faba) were washed and dried in a forced circulation oven (50ºC) and milled separately in a grinder (CHINCAN model FW 100, China). Broad beans were also peeled before drying. Andean potatoes (Solanum andigena) were boiled 20 min, then peeled and processed until an homogeneous purée was obtained.

Linear programming application to obtain the nutrition improvement of sweet bread

Linear programming was used to determine the proportions in which the flours (wheat, broad bean, amaranth and chia) had to be mixed so that both formulated breads (R2) and (R3) satisfied the macronutrient intake recommended by the Dietary Guidelines for Americans[14] consisting of a daily energy intake of 10-35% of protein, 20-35% of fats and 45-65% of carbohydrates, for which restrictions c, d, e, f, g and h were included. Recipe R2 was formulated without sensory restrictions while R3 was designed considering restrictions i, j and k (listed below) according to the preliminary sensory evaluations.

The minimum cost involved in nutrition enrichment was set as the objective function for calculation[11]. For each ingredient, both the nutrient content and the cost per 100 g were included. The linear programming model was carried out with Solver add-in of Microsoft Excel 2010 (Microsoft, Inc., Redmond, WA, USA). The model is as follows:

Objective function: Minimize.

$$\text{Cost}_{Af}(\$) = \sum_i \text{Costs} (\$)$$

Subject to the following restrictions:

a. A1, A2,…, Ai,…An. Where n≥0
b. A_{Af}=100g
c. $P_{Af} \geq P_{Af(min)}$ Where $P_{Af(min)}$=8.2 g
d. $P_{Af} \leq P_{Af(max)}$ Where $P_{Af(max)}$=12.3 g
e. $L_{Af} \geq L_{Af(min)}$ Where $L_{Af(min)}$=7.3 g
f. $L_{Af} \leq L_{Af(max)}$ Where $L_{Af(max)}$=12.7 g
g. $CH_{Af} \geq CH_{Af(min)}$ Where $CH_{Af(min)}$=24.6 g
h. $CH_{Af} \leq CH_{Af(max)}$ Where $CH_{Af(max)}$=45.1 g
i. $A_w \geq 80$ g
j. $A_{bb} \leq 2$ g
k. $A_{ch} \leq 10$ g

Where i, …, n: raw materials used for the formulation. Restriction "a" established that the solutions solved by the program, regarding the proportions of raw material, had to be positive. Restriction "b" set the weight of formulated food, in this case: 100 g. Restrictions c-d, e-f and g-h referred to the macronutrient content complying

with the recommended proportions. They corresponded to the following equations:

$$P_{Af} = \frac{E_{Af(P)}}{Eu_P} \quad \text{Where} \quad E_{Af(P)} = \frac{(\% \, P)}{100} E_{Af}$$

$$L_{Af} = \frac{E_{Af(L)}}{Eu_L} \quad \text{Where} \quad E_{Af(L)} = \frac{(\%L)}{100} E_{Af}$$

$$CH_{Af} = \frac{E_{Af(CH)}}{Eu_{CH}} \quad \text{Where} \quad E_{Af(CH)} = \frac{(\%CH)}{100} E_{Af}$$

Total energy: $E_{Af} = E_{Af}(P) + E_{Af}(L) + E_{Af}(CH)$

Restrictions i, j and k corresponded to the minimum content of wheat flour (Aw) and the maximum contents of broad bean (Abb) and chia (Ach) flours that could be incorporated to the bread, respectively. These restrictions considered that higher values of broad bean, chia and amaranth flours could cause negative impacts on the flavor, texture and acceptability of the products.

Equation system

Mass balance for proteins:
$(A_1P_1 + A_2P_2 + ... A_iP_i)(\Delta_{Total})(\Delta P_{Total}) = A_{Af}P_{Af}$
Mass balance for lipids:
$(A_1L_1 + A_2L_2 + ... A_1L_i)(\Delta_{Total})(\Delta L_{Total}) = A_{Af}L_{Af}$
Mass balance for carbohydrates:
$A_{Af} = A_1(\Delta_1) + A_2(\Delta_2) + ... A_i(\Delta_i) = (A_1 + A_2 + ... + A_i)(\Delta_{Total})$
Global mass balance:

Where:

$E_{Af(P)}$, $E_{Af(L)}$, $E_{Af(CH)}$: Energy provided by proteins, lipids and carbohydrates, respectively.

%P, %L,%, %CH: Percentage of calories that proteins, lipids and carbohydrates provided, respectively.

E_{uP}, E_{uL}, E_{uCH}: Atwater Coefficients (4; 9 and 4 kcal/g of proteins, lipids and carbohydrates, respectively).

A_{Af}: Amount of formulated food (g).

A_i: Amount of raw material "i" for obtaining formulated food (g).

Δ_{Total}: Change of weight during processing (g).

P_i, L_i, CH_i: Content of proteins, lipids and carbohydrates in raw material "i" (g).

ΔP_{Total}, ΔL_{Total}, ΔCH_{Total}: Retention of proteins, lipids and carbohydrates during processing.

P_{Af}, L_{Af}, CH_{Af}: Content of proteins, lipids and carbohydrates in the formulated food (g).

Preparation of bakery product

Two sweet nutritionally improved bakery products (R2 and R3) were formulated modifying a standard recipe (R1). It was based on wheat flour and potato in a 50:50 ratio, 9% sugar; 6% butter; 9% egg; 6% milk; 3% yeast and 0.1% salt. In the experimental samples, the wheat flour was replaced by wheat, amaranth, broad beans and chia flours. The proportions of each one were determined by linear programming for recipes R2 and R3.

Flour and other ingredients (mashed potatoes, butter, eggs) were mixed with yeast in warm milk and sugar (ferment), kneaded and let to stand for 15 minutes in a warm place, then degassed and cut into strips to make twisted threads of approximately 10 g each, to stand again for another 15 min and baked at 180ºC for 30 min. The samples were milled (particle size < 10 mm) in a centrifugal mill (CHINCAN model FW 100, China), vacuum packed in polyethylene bags and stored at 4ºC for further chemical analysis.

Proximate composition

The proximate composition was determined by official AOAC techniques 15: moisture (method 925.10), ashes (method 923.03), lipids (method 963.15), and carbohydrates (by difference). Total nitrogen was determined (method 920.87) and a 6.25 conversion factor was used to calculate total protein content. Total dietary fiber (method 985.29) was also determined. All analyses were carried out in triplicate.

Protein quality

Chemical Score was determined by calculation[5] based on essential amino acids composition of all the ingredient proteins used in the formulation. Amino acids composition of the raw materials was reviewed in the literature[16]. The standard protein used corresponds to protein for schoolchildren (mgAA/g Protein)[17].

Lipid profile

Lipid profile was determined using the UNE 55-037.73 AENOR technique. Lipids were extracted by the Soxhlet method, saponified and esterified with sodium methylate in methanol and sulphuric acid and then injected into gas chromatograph equipment (Hewlett Packard 6890) with DB-225 column (length 30 m, internal diameter 0.25 mm; thickness 0.25 um film). The identification of fatty acids was performed by comparison with a standard Sigma Aldrich (Supelco 18919-AMP1-Mix F.A.M.E. C4C24). All analyses were conducted in triplicate.

Microbiological tests

Total mesophiles, coliforms, moulds and yeasts were determined by ICMSF techniques[18], in bakery products. All analyses were carried out in triplicate.

Sensory evaluation

The sensory evaluation and acceptability of fresh recipes R1, R2 and R3 were evaluated with 60 schoolchildren (between 4 and 9 years old) and 100 adults. A structured hedonic scale of 9 points with the ends (1) "I am very disgusted" and (9) "I like it very much" was used for the

adults; and for the children, a scale with two extremes: "I like it" and "I dislike it". The fresh samples were presented to consumers in a plate with samples of about 10 g each. The test was completed by adults, with CATA (check-all-that-apply) questions[19]. For this purpose, a list of 25 terms was presented to the consumers asking them to mark all the ones they considered appropriate to describe the product.

Statistical analysis

Results were expressed as mean ± standard deviation (SD). The statistical analysis was done by using one way analysis of variance (ANOVA), followed by the Tukey test to assess differences between group means. Differences were considered significant at p<0.05. Statistical analyses were performed with Statistic for Windows version 9.0 (Analytical Software, Tallahassee, FL, USA).

For the CATA question, the frequency each term was mentioned was determined by counting the number of consumers who used that term to describe each sample. A multiple correspondence analysis (MCA) was performed on the frequency table, containing responses to the CATA question in order to compare sensory characteristics of the samples and to differentiate them[20]. An XLStat trial software (Copyright © 2015 Addinsoft) was used to conduct the above analyses.

RESULTS
Linear programming

Linear programming determined the appropriate proportions of flours to be mixed so as to obtain the nutritionally enhanced bakery products, R2 and R3, from control recipe R1 (100% wheat flour). They were: wheat/broad bean/chia/amaranth 64/22/13/0 (R2) and 83/2/4/11 (R3).The prices of the formulations R2 and R3 (100 g) were increased from $2.13 (R1) to $2.84 and $2.92, respectively.

Proximate composition

Bakery products obtained complied with the Argentine Food Code21regarding the maximum moisture content for this type of products (29 g/100 g food): R1 (21.31±0.27), R2 (22.58±0.17) and R3 (19.58±0.08). Table 1 shows the proximate composition of the raw material and products obtained. Incorporating amaranth, broad beans and chia flours to the formulation in the appropriate proportions, allowed bakery products to obtain significantly higher protein and lipid content (ρ<0.05). The contribution of total dietary fiber increased significantly (ρ<0.05) with the incorporation of the other flours.

Recipes R2 and R3 also had an energetic balance from macronutrients close to the proportions recommended by the Dietary Guidelines for Americans[14]; while in recipe R1 the highest energy intake came from carbohydrates (75 carbohydrates kJ/100 total kJ).

PROTEIN QUALITY

All recipes presented lysine as limiting amino acids. R1 had the lowest chemical score value (46%). The incorporation of amaranth, broad bean and chia flours were used to increase the Chemical Score of recipes R2 (95%) and R3 (91%).

Lipid profile

Table 2 shows the fatty acids profile of formulated bakery products. The saturated fatty acid content was higher in the control recipe R1 than R2 and R3 consisting mainly of palmitic, stearic and myristic fatty acids. The monounsaturated fatty acids decreased and the polyunsaturated fatty acids content increased, mainly ω3 fatty acid, with nutrition improvement. The incorporation of chia flour was mainly responsible for the improvement of w3: w6 ratio in R2

Table 1. Proximate composition and energy content of flours and bakery products.

	Potatoes	Wheat flour	Amaranth flour	Broad beans flour	Chia flour	Recipe 1 (Control)	Recipe 2 (Product)	Recipe 3 (Product)
Ash (g/100g db)	3.64±0.04[a]	0.41±0.05[b]	3.64±0.36[a]	4.64±1.15[a]	4.15±0.13[a]	1.01±0.03[b]	1.49±0.08[b]	1.81±0.12[b]
Proteins (g/100g db)	9.98±0.94[de]	11.43±0.62[cd]	16.57±0.44[b]	21.94±0.92[a]	20.9±1.22[a]	7.73±0.23[e]	13.89±0.15[cd]	11.16±0.11[bc]
Fats (g/100g db)	0.76±0.24[e]	1.12±0.12[e]	7.83±0.64[d]	1.53±0.57[e]	19.9±0.21[a]	9.02±0.30[d]	15.28±0.49[b]	10.96±0.37[c]
Carbohydrates (g/100g db)	85.62	87.04	71.96	71.90	55.07	82.23	69.34	76.07
Total dietary fiber (g/100g db)	8.05±0.75[c]	4.20±0.86[cd]	8.55±0.98[c]	23.9±2.19[b]	40.6±2.06[a]	0.53±0.30[d]	8.02±1.13[c]	6.35±0.37[c]
Protein energy (kJ/100g db)	167	192	276	368	351	130 (7*)	230 (12*)	188 (10*)
Fats energy (kJ /100g db)	28	42	293	59	748	339 (18*)	573 (29*)	414 (22*)
Carbohydrates energy (kJ /100g db)	1431	1455	1204	1204	920	1375 (75*)	1158 (59*)	1271 (67*)
Total energy (kJ /100g db)	1626	1689	1772	1626	2019	1843	1960	1873

Values are Means ± SD (n=3). Values with different letter in the same row are significantly different (ρ<0.05)
* Energy from proteins, fats or carbohydrates (kJ)/Total energy of product (kJ).

Table 2. Fatty acids profile of bakery products (g methyl esters/100 g fat).

Fatty acids	Recipe 1	Recipe 2	Recipe 3
C6:0 (Caproic acid)	0.50±0.02	0.63±0.01	0.44±0.01
C8:0 (Caprylic acid)	0.42±0.01	0.58±0.01	0.54±0.01
C10:0 (Capric acid)	1.05±0.02	1.48±0.02	1.50±0.01
C12:0 (Lauric acid)	1.44±0.02	1.93±0.01	1.08±0.01
C14:0 (Myristic acid)	6.83±0.02	7.27±0.01	7.63±0.02
C15:0 (Pentadecanoic acid)	0.87±0.02	0.80±0.01	0.82±0.01
C16:0 (Palmitic acid)	29.37±0.03	25.86±0.02	26.76±0.02
C17:0 (Margaric acid)	0.81±0.01	0.49±0.01	0.49±0.01
C18:0 (Stearic acid)	15.73±0.03	10.79±0.01	11.29±0.01
C20:0 (Arachidonic acid)	0.19±0.01	0.19±0.01	0.21±0.01
C14:1 (Myristoylic acid)	0.56±0.02	0.591±0.01	0.64±0.01
C16:1 (Palmitoleic acid)	1.65±0.02	1.33±0.01	1.55±0.01
C18:1n9 (Oleic acid)	31.12±0.03	27.95±0.02	27.68±0.03
C18:2n6t (Linolelaidic acid)	0.39±0.01	0.42±0.01	0.47±0.01
C18:2n6c (Linoleic acid)	7.69±0.02	11.79±0.01	9.65±0.01
C18:3n3 (Linolenic acid)	0.75±0.01	7.32±0.01	7.69±0.01
Total Saturated	57.49	50.34	50.95
Total Monounsaturated	33.66	30.12	30.09
Total Polyunsaturated	8.85	19.54	17.81
Total trans	0.398	0.42	0.47
Polyunsaturated / Saturated fatty acids	0.154	0.39	0.35
ω3:ω6	1/10	1/2	1/1

Values are Means ± SD (n=3).

and R3 products.

Microbiological quality

The products obtained complied with the microbiological characteristics (Table 3) established by the Argentine Food Code, Chapter XVII[21], which states that ready-to-eat cereal-based foods should have a maximum of 10^3 CFU/g of moulds and yeasts. Both products did not show growth of mesophiles or total coliforms. The limit established by the code is 5.104CFU/g and 100 MLN/g respectively.

Acceptability and sensory analysis

The acceptability of bakery products R1, R2 and R3 obtained with adult consumers was 80, 44 and 84% respectively. Recipes R1 and R3 had an average acceptability score of 7 on the hedonic scale, while R2 had only a 5. figure 1 shows the consumers' description of bakery products by CATA analysis and figure 2 shows the sensorial profile. Multiple correspondence analyses (MCA) explained 99.87% of the variance, and the bakery products were differentiated into three groups. The terms used by less than 10% of the consumers in all recipes were deleted. Recipes R1 and R3 were more frequently described with the following terms: good appearance and quality, soft texture, moist and tender,

Table 3. Microbiological quality.

Microorganisms	Established by the CAA	Recipe 1	Recipe 2	Recipe 3
Mesophiles	Max. 5.10^4 CFU*/g	Absence	Absence	Absence
Coliforms	Max. 100 MLN**/g	Absence	Absence	Absence
Molds and yeasts	Max. 10^3 CFU*/g	$< 10^3$	$< 10^3$	$< 10^3$

CAA: Corrected amino acid
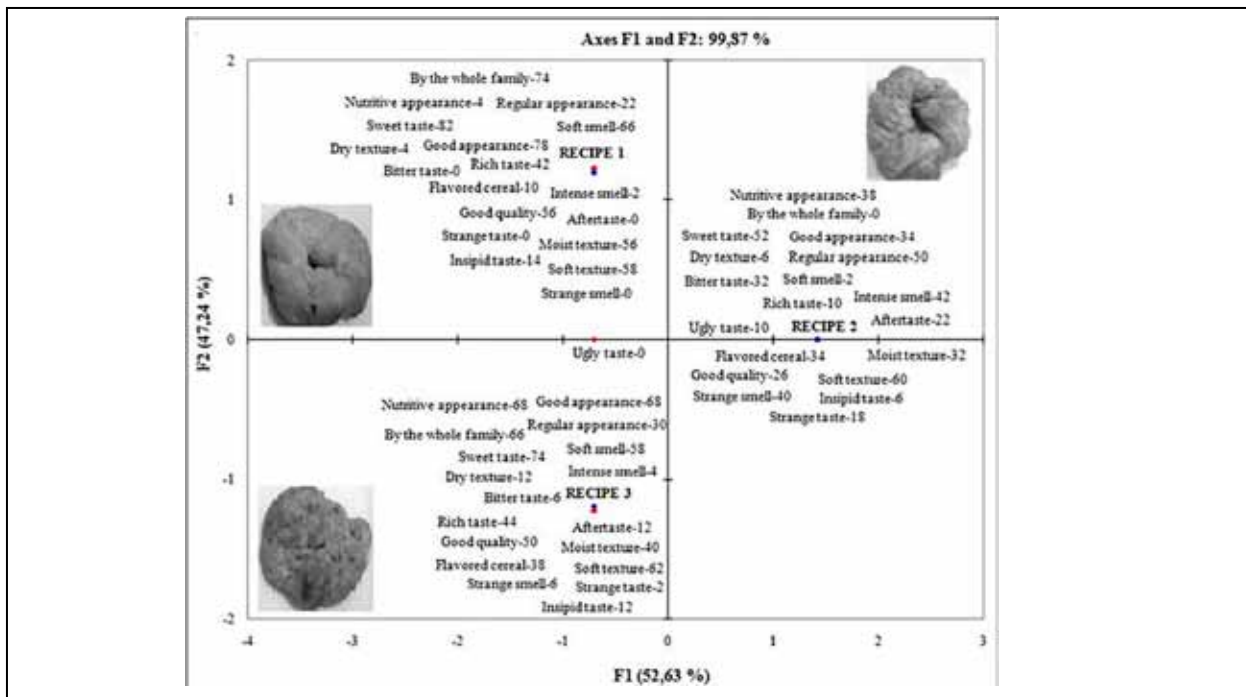CFU: Colony Forming Units
MLN: Most Likely Number

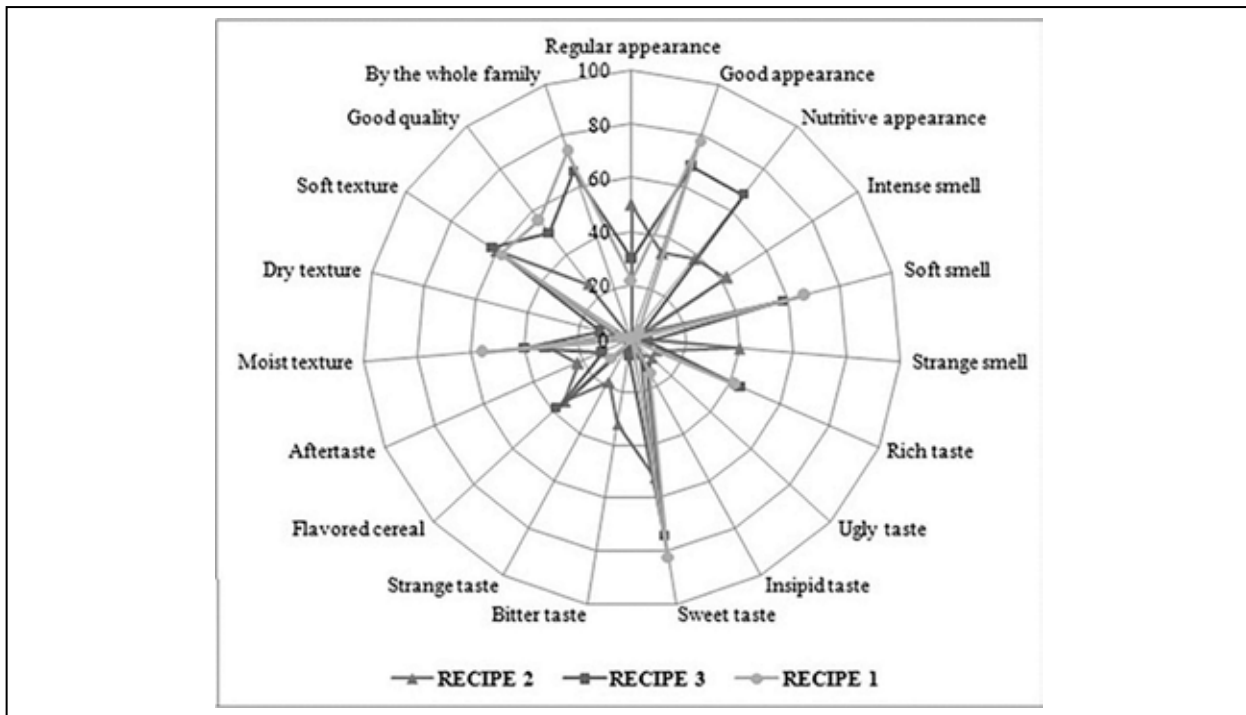**Figure 1.** Sensorial attributes of bakery products.

Figure 2. Sensorial profile of bakery products.

rich and sweet taste; considering them as food that could be consumed by the whole family. In addition, R3 was described as a nutritive product. Bakery product R2 was more frequently described by consumers, with negative terms as intense smell, bitter, bad and strange flavor. Recipe R2 contained many nutrients which could affect its palatability. Based on preliminary results, it was determined that the bean and chia flours were responsible for affecting the palatability of the products. Therefore it was necessary to restrict the incorporation of these raw materials with the restrictions included in the linear programming in order to obtain R3. The acceptability study with school-age children (6-10 years) was carried out only with products R1 and R3, which had been accepted by adult consumers. The sensory study revealed similar acceptance for both products (from 65% for R1 and 60% for R3).

DISCUSSION

The combination of the raw materials in the proportions given by the linear programming used to obtain the nutritionally improved products, R2 and R3, implied an additional cost compared to the control recipe R1 of 33 and 37%, respectively. However, recipe R1 had a significantly lower fiber content compared to R2 and R3 ($\rho<0.05$). Also recipes R2 and R3 presented a significant increase ($\rho<0.05$) in protein and lipid content with respect to R1 (Table 1), as well as a nearby contribution of energy from each nutrient according to the Dietary Guidelines for Americans[14]. In addition, the products had microbiological quality within the limits established by the Argentine Food Code[21].

The nutrition improvements in R2 and R3 exceeded those obtained by Silveira-Coelho and Salas-Mellado[2], who used a mixture of wheat: soybean:chia:flax flours (80:10:5:5), achieving a protein improvement of 13%, lipid 10%, ashes 20% and fiber 6.7 times. Whole-wheat breads have higher dietary fiber content compared to white breads.

Currently, there is a growing interest in increasing dietary fiber intake for its physiological and metabolic benefits. Dietary guidelines suggest adequate intake of dietary fiber which can vary between 27-40 grams per kilograms a day[3]. Fiber increased in recipes R2 and R3 with the incorporation of broad bean, amaranth and chia flours, since they were incorporated as integral flours. Consumption of 100 grams of R2 would cover 20.1-29.7% of daily fiber intake and R3, 15.9-23.5%, while R1 would cover only 1.3-2.0%. Moreover, the Argentine Food Code, Chapter XVII[21], considers that food is a source of dietary fiber when it contains minimally 3 grams fiber/100 grams of food. Both R2 and R3 recipes met this condition.

Recipe R1 presented lysine as a limiting amino acid. The wheat flour was the only raw material of R1 that presented lysine as a limiting amino acid. However the other ingredients (potato, milk, and egg) were not enough to compensate this limitation. The incorporation of amaranth, broad bean and chia flours were used to increase the Chemical Score of recipes R2 and R3. This was due to the great contribution

of lysine from legumes and mainly, to the amino acid complementation that exist between these flours with wheat. The obtained values for R2 and R3 were similar to those found by Pinto Kramer[22] in other bakery foods nutritionally enhanced: for example, cookies elaborated with 70:30 soy and oats (SCh=96%); sweet biscuits with 80:20 soybean/rice (SCh=94%); and biscuits made with 60:40 soybean/amaranth (SCh=92%), with lysine as limiting amino acid in all cases. Acevedo-Pacheco and Serna-Saldívar[23] enriched corn and wheat tortillas with 6% of defatted soybean flour and achieved an increase in protein intake of 25 and 23% respectively, with chemical score improved from 49 to 64%.

The fatty acid profile improved in R2 and R3 in relation to R1 (Table 2) with the incorporation of the amaranth, bean and chia flours. The results obtained were comparable with Silveira-Coelho and Salas-Mellado[2] using a mixture of wheat: soy: chia:flax (80:10:5:5) achieving a reduction of saturated and monounsaturated fatty acids and increasing polyunsaturated fatty acids. Osuna et al.[24] obtained similar results enriching wheat breads with soy and flax flours in different proportions. Recommended w3: w6 ratio is minor to 1/5 obtaining cardiovascular health benefit and increasing the formation of eicosanoids from araquidonic acid[24,25], and recipes R2 and R3 complied with that recommendation (Table 2). All products provide trans-fatty acid amounts smaller than the maximum allowed according Chapter III, Article 155 tris, of the Argentine Food Code[21], which states trans-fatty acid content should not be greater than 5% of total fats in processed foods.

Recipes R1 and R3 presented acceptability higher than 80% and were described with positive and similar terms among them, such as good appearance and quality, soft texture, moist and tender, rich and sweet taste, by the whole family (Figure 1). While recipe R2 presented bad acceptability and was described with negative terms such as bad, bitter and strange flavor (Figure 1). Recipe R2 contained many nutrients which could affect its palatability; also the high fiber content could affect acceptability[26]. The amounts of broad bean and chia flours were restricted to a maximum so as not to affect the palatability of the final product according to preliminary sensorial tests. Sandri et al.[27] also observed that chia flour alone or in high proportions is not suitable for bread production and with the substitution of up to 14% chia flour they were able to obtain similar acceptability scores for their standard wheat bread counterparts. On the other hand, Belghith-Fendri et al.[28] concluded that the substitution with broad bean flour could be up to 15% in bakery products without altering the sensory scores. Martínez et al.[29] studied the substitution of wheat flour for amaranth whole flour to formulate pastas and concluded that the maximum level of substitution of amaranth flour should be 30% so as not to observe significant differences in the sensory evaluation.

The proportions used for R3 formulation were obtained with the restrictions incorporated in the linear programming. Recipes R1 and R3 presented similar acceptability. This result

was favourable for R3, since a very high percentage of children present innate refusals to taste new foods, a phenomenon that is called food neophobia[30]. This behavior is one of the causes of poor diets in children who, in general, express their rejection towards food rich in fiber and protein. The high nutritional value and acceptability of bakery product R3 would allow considering it as a possible snack to be included in the school diet.

CONCLUSIONS

Linear programming proved to be a suitable tool for formulating nutritionally improved bakery products. The restrictions considered in the programming with regard to the maximum amounts of raw materials that give negative sensorial characteristics, allowed obtaining a highly accepted product. Therefore, these restrictions allowed counteracting the non-linearity that the sensorial characteristics have in the linear programming.

The wheat/broad bean/chia/amaranth flour mixture in the proportions resulting from the linear programming allowed obtaining a bakery product with high nutritional value and minimum cost. The bakery product obtained had good acceptability in adults and schoolchildren; therefore, this product could be incorporated as a snack in school cafeterias.

REFERENCES

1. Mastromatteo M, Danza A, Lacce L et al. Effect of durum wheat varieties on bread quality. Int J Food Sci Technol 2013; 49(1): 72-81.
2. Silveira-Coelho M, Salas-Mellado MM. Effects of substituting chia (Salvia hispanica L.) flour or seeds for wheat flour on the quality of the bread. LWT-Food Sci Technol 2015; 60: 729-736.
3. Food and Agriculture Organization. Report of the joint FAO expert consultation on the Family nutrition guide. Rome, 2006.
4. Pérez-Quirce S, Collar C, Ronda F. Significance of healthy viscous dietary fibres on the performance of gluten-free rice-based formulated breads. Int J Food Sci Technol 2014; 49: 1375-1382.
5. Giménez MA, Drago SR, De Greef D, Gonzalez RJ, Lobo MO, Sammán NC. Rheological, functional and nutritional properties of wheat/broad bean (Vicia faba) flour blends for pasta formulation. Food Chem 2012; 134: 200-206.
6. Steffolani E, Martinez MM, León AE, Gomez M. Effect of pre-hydration of chia (Salvia hispanica L.) seeds and flour on the quality of wheat flour breads. LWT-Food Sci Technol 2015; 61: 401-406.
7. Heidari Z, Feizi A, Azadbakht L, Mohammadifard N, Maghroun M, Sarrafzadegan S. Usual energy and macronutrient intakes in a large sample of Iranian middle-aged and elderly populations. Nutr Diet 2018 doi: 10.1111/1747-0080.12431.
8. Bassett MN, Gimenez MA, Romaguera D, Sammán N. Nutritional status and food intake of populations from high altitude regions of the Northwest of Argentine. Arch Latinoam Nutr 2013; 63 (2): 114-124.
9. Nascimento AC, Mota C, Coelho I et al. Characterization of nutrient profile of quinoa (Chenopodium quinoa), amaranth (Amaranthus caudatus), and purple corn (Zea mays L.)

consumed in the North of Argentina: Proximate, minerals and trace elements. Food Chem 2014; 148: 420-426.
10. Ogrodowska D, Zadernowski R, Czaplicki S, Derewiaka D, Wronowska B. Amaranth Seeds and Products – The Source of Bioactive Compounds. J Food Nutr Sci 2014; 64(3): 165-170.
11. Sheibani E, Moghaddam AD, Sharifan A, Afshari Z. Linear Programming: An Alternative Approach for Developing Formulations for Emergency Food Products. J Sci Food Agric 2017 doi: 10.1002/jsfa.8612.
12. Jomaa LH, McDonnel E, Probart C. School Feeding Programs in Developing Countries: Impacts on Children's Health and Educational Outcomes. Nutr Rev 2011; 69: 83-98.
13. Macías S, Binaghi MJ, Zuleta A, Ronayne de Ferrer P, Costa K, Generoso S. Development of cookies with partial substitution of wheat flour with mesquite (Prosopis alba) flour and oats for social plans. Rev Ven Cienc Tecnol Alim 2013; 4 (2): 170-188.
14. U.S. Department of Agriculture; U.S. Department of Health and Human Services. Dietary Guidelines for Americans, 7th ed.; Government Printing Office: Washington, DC, USA, 2010.15. AOAC, Association of Official Analytical Chemists (AOAC). Official Methods of Analysis. (Available from: http://www.aoac.org/, accessed 1 May 2018).
16. Souci SW, Fachmann W, Kraut H. Food Composition and Nutrition Tables. 7th revised and completed edition. MedPharm-Scientific Publishers, 2008 (ISBN 9780849341410).
17. Food and Agriculture Organization/World Health Organization/United Nations University. Report of the joint FAO/WHO/UNU expert consultation on the Energy and Protein Requirements. Technical Report Series 724. Geneva, 1985.
18. International Commission on Microbiological Specifications for Foods (ICMSF). (Available from: http://www.icmsf.org, accessed 1 May 2018).
19. Ríos F, Lobo M, Sammán N. Acceptability of beehive products as ingredients in quinoa bars. J Sci Food Agric 2017 doi: 10.1002/jsfa.8452.
20. Vidal L, Barreiro C, Gómez B, Ares G, Giménez A. Influence of information on consumers' evaluations using check-all-that-apply questions and sorting: A case study with milk desserts. J Sensory Stud 2013; 28: 125-137.
21. Argentine Food Code. (Available from: www.anmat.gov.ar/alimentos/normativas_alimentos_caa.asp, accessed 20 May 2018).
22. Pinto Kramer A, Brito G, Beccio B, Longo P, López L. Digestibility corrected amino acid score (PDCAAS) in protein complementation. Buenos Aires, Argentina. (Available from: www.fmed.uba.ar/depto/nutrinormal/pdcaas_y_complementacion_proterica.pdf, accessed 1 May 2018).
23. Acevedo-Pacheco L, Serna-Saldívar SO. In vivo protein quality of selected cereal-based staple foods enriched with soybean proteins. Food Nutr Res 2016; 60: 1, 31382.
24. Osuna MB, Romero AM, Judis MA, Bertola NC. Enrichment of the fatty acids profile of breads Replaced with functional flours blends. Int J Res Eng Technol 2016; 5(9): 224-232.
25. Rahmawaty S, Charlton K, Lyons-Wall P, Meyer B. Factors that influence consumption of fish and omega–3-enriched foods: A survey of Australian families with young children. Nutr Diet 2013; 70: 286-293.
26. Grigor JM, Brennan CS, Hutchings SC, Rowlands DS. Review: The sensory acceptance of fibre-enriched cereal foods: a meta-analysis. Int J Food Sci Technol 2016; 51: 3-13.
27. Sandri LTB., Santos FG, Fratelli C et al. Development of

gluten-free bread formulations containing whole chia flour with acceptable sensory properties. *Food Sci Nutr.* 2017; 1-8.

28. Belghith-Fendri L, Chaari F, Kallel F et al. *Pea and Broad Bean Pods as a Natural Source of Dietary Fiber: The Impact on Texture and Sensory Properties of Cake. J Food Sci.* 2016 doi: 10.1111/1750-3841.13448.

29. Martinez CS, Ribotta PD, Añón MC, León AE. *Effect of amaranth flour (Amaranthus mantegazzianus) on the technological and sensory quality of bread wheat pasta. Food Science and Technology International* 2014, 20(2): 127-135.

30. Rodríguez-Tadeo A, Patiño Villena B, Urquidez-Romero R et al. *Food Neophobia: Impact on Eating Habits and Acceptance of Healthy Foods in School Lunch. Nutr Hosp* 2015; 31(1): 260-268.