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Fatty acid profile of lipid-rich food consumed in Paraguay

Perfil de ácidos grasos de alimentos ricos en lípidos consumidos en Paraguay

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ABSTRACT

The present study aims to establish the fatty acid profile of a variety of traditional foods consumed regularly in Paraguay. Thirty-two high-lipid content foods were evaluated by gas chromatography coupled with a flame ionization detector (GC-FID). Meat and dairy products were found to present high levels of saturated fatty acids, and this led to an increase in the atherogenicity and thrombogenicity indices of these products. Among the monounsaturated acids evaluated, oleic acid (18:1n-9c) was mainly found in olives (71.7%) and chipa (62.7%), which had been industrially prepared with the addition of oleic acid. Milk-based ice cream (5.1%) and chipa guazú (3.8%) presented the highest content of trans fatty acids. The n-6/n-3 fatty acids ratio obtained for the traditional sopa Paraguaya and empanada (fried pasty) was higher than 37:1; this can be attributed to the addition of soybean and corn oils in the preparation of these foods. The data evaluated and presented in this study can contribute toward the improvement of eating habits among the Paraguayan population, as well as help combat the risk factors commonly associated with bad eating habits and chronic health issues.

Keyword: Cardiovascular diseases; Index of atherogenicity; Nutritional quality; n-6/n-3 ratio; Traditional foods.

RESUMEN

El presente estudio tuvo como objetivo establecer los perfiles de ácidos grasos de una variedad de alimentos tradicionales que se consumen regularmente en Paraguay. Se evaluaron treinta y dos alimentos con alto contenido de lípidos mediante

cromatografía de gases acoplada a detector de ionización de llama (GC-FID). Los productos cárnicos y lácteos presentaron un elevado nivel de ácidos grasos saturados, aumentando los índices de aterogenicidad y trombogenicidad. Entre los monoinsaturados, el ácido oleico (18: 1n-9c) se encontró principalmente en aceitunas (71,7%) y chipa (62,7%), este último preparado industrialmente por adición de ácido oleico. En cuanto al contenido de ácidos grasos trans, los valores más altos se encontraron en los helados a base de leche (5,1%) y chipa guazú (3,8%). Los valores de la relación n-6 / n-3 fueron superiores a 37:1 en sopa paraguaya y empanada (frita) debido a la adición de aceite de soja y maíz utilizado en la preparación de alimentos. Los datos evaluados y presentados en este estudio pueden contribuir a la mejora de los hábitos alimentarios de la población paraguaya, así como ayudar a combatir los factores de riesgo comúnmente asociados con los malos hábitos alimentarios y los problemas crónicos de salud.

Palabras clave: Alimentos tradicionales; Calidad nutricional; Enfermedades cardiovasculares; Índice de aterogenicidad; Relación n-6/n-3.

INTRODUCTION

The eating habits of a country are intrinsically related to the culture of its people¹. Having knowledge of the nutritional composition of the foods people consume is of extreme importance as health and well-being are directly related to food consumption and frequency^{2,3}. Paraguay has an ample variety of traditional foods, which include chipa, reviro, mbeju, empanada (fried pasty), chipa guazú, and sopa Paraguaya, among others^{1,4}. These traditional foods are essentially home-made foods which are prepared regularly and consumed daily by a majority of the Paraguayan population, who often lack information regarding the nutritional composition of these foods. Apart from the aforementioned traditional foods, yogurt, milk, and vegetable oils (soybean and sunflower) are also widely consumed by Paraguayans similarly to other countries⁴.

Considering the close relationship between eating habits and chronic disease development, it is undoubtedly clear that having a better understanding of the nutritional composition of the foods people consume will help significantly reduce the development of these diseases among a significant portion of the population². Cardiovascular diseases (CVDs), which include cerebrovascular diseases, heart diseases and blood vessel disorder, have been reported as the main causes of death in both Paraguay and Brazil⁵. Limited access to health care coupled with demographic and socioeconomic factors, as well as local habits and cultural differences, in terms of alcohol consumption, smoking, obesity, alteration of dietary habits, urbanization, stress, and sedentary lifestyle, favor atherogenic dyslipidemia, which contributes toward the heightened incidence of CVDs in Latin America and in the world at large⁶. One of the main risk factors associated with CVDs is unhealthy eating habits, particularly related to the consumption of high calorie foods rich in salts and fats, which often lead to the development of hypertension, diabetes, elevated lipids and obesity⁷.

Indeed, while having knowledge of the nutritional profile of the foods consumed is clearly important, gaining a better understanding of the lipid profile of these foods is also vital for ensuring healthy dietary habits among the population³. A number of studies published have determined the nutritional quality indices of foods based on lipid profiles, and have associated these indices to quality of life and health of

individuals who consume these foods²). Among the main indices related to the nutritional quality of foods include the ratio of omega-6 and omega-3 polyunsaturated fatty acids (n-6/n-3), the ratio of total poly-unsaturated fatty acids (Σ PUFA) and saturated fatty acids (Σ SFA) (Σ PUFA/ Σ SFA), and atherogenicity (IA) and thrombogenicity (IT) indices^{8,9,10,11,12}.

The present study aims to establish the fatty acid profiles of a variety of traditional foods consumed regularly in Paraguay. The study will shed light on the contents of saturated, monounsaturated, polyunsaturated, and trans fatty acids (TFA), as well as the indices of nutritional quality of these foods. The results obtained from this study will help construct nutritional tables of the foods traditionally consumed in Paraguay, while aiding in the implementation of public health policy measures targeted at reducing the incidence of diseases related to poor eating habits and raising awareness among the population regarding dietary habits.

MATERIALS E METHODS

Sampling

Ten food groups were created based on a questionnaire administered to 150 people regarding eating habits in the previous 24 hours¹³; respondents were college/university adult students and who lived in the Ciudad del Este metropolitan area. A description of the ten food groups separated based on the questionnaire can be found in table 1.

The selection of the foods was performed based on the fat content using the information provided in the NUTRISYS 2.0 table calculated during a 24 hour period. Out of a total of 87 foods described, only 32 foods were selected (Table 1). The samples were collected between May and October 2019. Three distinct batches of each food were collected; these batches were then homogenized in order to create a single, representative sample of the food.

Fatty acid profile

Lipids were extracted from foods based on the methodology developed by Bligh et al.¹⁴, maintaining the ratio of 2:2:1 for chloroform, metanol, and water (v/v), respectively. The extraction of lipids from yogurts was conducted in duplicate based on the methodology developed by Folch et al.¹⁵. Lipids extracted were kept at -20 °C until analysis.

Table 1. Lipid content of selected food groups.

Food Group	Food	Lipids (%)
Desserts	Milk-based ice cream	12.8
Oils or fats	Sunflower oil	-
	Soybean oil	-
	Mayonnaise	89.8
	Margarine	80.7
Dairy products	Cow milk, whole	6.4
	Cow milk, reduced fat	3.5
	Butter	52.6
	Yogurt, whole milk	13.7
	Paraguayan cheese, whole milk	14.1
	Mozzarella cheese, whole milk	20.3
Meats and eggs	Beef	20.9
	Chicken meat	11.6
Processed meat	Raw eggs	12.2
	Sausages	46.6
	Hot dog	39.0
	Ham	25.4
Dried vegetables	Red beans	10.0
Fruits and nuts	Avocado	9.4
	Olive	11.0
	Peanuts	30.0
Cereals, tubers and derivatives	Mbeju	22.4
	Cheese bread	58.0
	Tortilla	48.9
	Noodles	5.0
	Chipa	16.0
	Reviro	54.0
Fast Food	Sopa Paraguaya	12.3
	Empanada, fried	19.8
	Chipa guazú	42.3
	Mixto	27.1
	Tenderloin sandwich	15.0

Using lipids extracted from foods, fatty acids were derivatized into fatty acid methyl esters (FAMES) based on the method reported by Hartman et al.¹⁶ and adapted by Santos et al.¹⁷. Approximately 25 mg of the lipid was weighed in a conical tube, and the methylation reaction was conducted by the addition of 4 mL solution of NaOH/MeOH at 0.5 mol L⁻¹. The mixture was subjected to an ultrasonic bath for 6 min (E 120H, Elma Schmidbauer®, 37 kHz and 750 W, Germany). Thereafter, a 5 mL solution of NH₄Cl and H₂SO₄ were added into MeOH in the ratio of 1:1.5:30 (m/v/v), respectively, and the mixture was again subjected to a 6 min ultrasonic bath. Phase separation was carried out through the addition of 4 mL saturated solution of NaCl, followed by vigorous stirring for 30 sec, subsequently, 2 mL isooctane was added to the mixture (99% chromatography grade, Sigma, St. Louis, MO, USA), and this was followed by vigorous stirring for another 30 sec. Finally, the mixture was kept at rest at -4 °C for 24 h for phase separation. The organic phase (superior part) containing the FAMES was subjected to chromatography analysis.

The analysis of the FAMES was conducted using gas chromatography (model TR-1310, from Thermo Scientific, USA), equipped with TR-FAME column (120 m length, 0.250 mm internal diameter and 0.250 µm film), and flame ionization detector, operating in split mode using a flow rate of 120 mL min⁻¹. The gas flow conditions applied were as follows: 30 mL min⁻¹ H₂ carrier gas, 40 mL min⁻¹ N₂ auxiliary gas, and 300 mL min⁻¹ synthetic gas. The temperatures of 230 and 225 °C were applied for the injector and detector, respectively. The column temperature was initially set at 180 °C for 12 min, followed by heating up to 210 °C at a rate of 5 °C/min; temperature was maintained at 210 °C for 1 min, followed by heating up to 240 °C at a rate of 2.5 °C/min; finally, temperature was kept at 240 °C for 14 min. Injections were performed in triplicate and the volume of injection applied was 1 µL. FAMES were identified through a comparison of the retention times of the components of the samples relative to the pattern of FAMES (Supelco® 37 Component FAME Mix, Sigma Aldrich, St. Louis, USA). Peak areas were determined with the aid of the Chromeleon 7 software; results obtained were expressed as percentage of relative area (%).

The validation of the FAMES identity was performed using gas chromatography coupled to mass spectrometry (GC/MS) (TRACE 1300 equipped with automatic sampler TriPlus RSH and mass analyzer ISQ Single Quadrupole MS, from Thermo Scientific, USA). Helium was used as a carrier gas, and was applied at a flow rate of 1.1 mL min⁻¹, with the injector operated at 230 °C. The ion source was kept at 200 °C and MS transfer line was set at 240 °C. The data processing was conducted using the software ThermoXcalibur, version 2.2 (from Thermo Scientific). The FAMES pattern and the samples were subjected to monitoring under complete scanning

(SCAN) at m/z 25.0–550. The conditions adopted for the chromatography ramp and column were similar to those described in the GC-FID analysis.

Lipid nutritional quality indices

The nutritional quality of the lipid content was determined based on the indices described in the literature which determine the relationship between the representative fatty acids from the foods and those that play an influential role in the dietary habits of the individuals – these included omega 3 fatty acids (Σn-3), omega 6 fatty acids (Σn-6), the sum of monounsaturated fatty acids (ΣMUFA), and the sum of polyunsaturated fatty acids (ΣPUFA). The evaluation of the nutritional quality of the foods was conducted based on three elements: i) the index of atherogenicity (IA) (equation 1); ii) the index of thrombogenicity (IT) (equation 2); and iii) the ratio of omega 6 /omega 3 (Σn-6/Σn-3) fatty acids.

$$IA = \frac{[12:0 + (4 \times 14:0) + 16:0]}{(MUFA + \Sigma n-6 + \Sigma n-3)} \quad (\text{equation 1})$$

$$IT = \frac{(14:0 + 16:0 + 18:0)}{[(0.5 \times MUFA) + (0.5 \times \Sigma n-6) + (3 \times \Sigma n-3) + (\Sigma n-3 / \Sigma n-6)]} \quad (\text{equation 2})$$

Statistical Analysis

The results obtained (in triplicate) for the foods investigated were presented as mean ± standard deviation. Data were analyzed using the Past Software 2.17c¹⁸. The most predominant fatty acids and the indices of nutritional quality were subjected to principal component analysis (PCA) and the Pearson's correlation coefficient tests.

RESULTS

Fatty acids

A total of 33 fatty acids were quantified in the lipid content of foods. Among the long-chain saturated fatty acids (SFA), myristic (C14:0), palmitic (C16:0), and stearic (C18:0) acids were the most predominant, with C16:0 being the most abundant among the samples evaluated, tables 2 and 3 show the fatty acid profiles investigated in this study.

Figure 1 shows the graph of scores, PCA2 vs. PCA1, based on the distribution of the most predominant fatty acids, with 97.4% classified under 3 food groups: rich in saturated fatty acids – C14:0, C16:0 and C18:0; linoleic acid – 18:2n-6 and oleic acid – 18:1n-9.

The animal-derived foods, such as meat and dairy products, presented the highest contents of C16:0 and C18:0 fatty acids (Figure 1 and Table 2). With regard to cow milk and other dairy products, the content of C14:0 was found to be superior to 12.0%; this is similar to the amount reported by other published studies¹⁹.

Considering all acids evaluated in this study, linoleic fatty acid (18:2n-6c) was the acid with the highest concentration

Table 2. Profile of saturated fatty acids (reported as % of total fatty acids) of the lipid fraction extracted from different foods consumed in Paraguay.

#Samples	C4:0	C6:0	C8:0	C10:0	C11:0	C12:0	C13:0	C14:0	C15:0	C16:0	C17:0	C18:0	C20:0	C21:0	C22:0	C24:0
1 Milk-based ice cream	0.00 -	0.19 ±0.02	0.17 ±0.01	0.00 ±0.02	0.00 -	1.24 -	0.00 -	2.13 ±0.03	0.18 ±0.01	33.99 ±0.12	0.23 ±0.01	18.53 ±0.20	0.00 -	0.34 -	0.00 ±0.02	0.00 ±0.01
2 Sunflower oil	- -	- -	- -	- -	- -	- -	- -	0.07 ±0.01	0.01 -	5.19 ±0.05	0.03 -	2.98 ±0.07	0.00 -	0.53 -	0.00 ±0.02	0.00 -
3 Soybean oil	- -	- -	- -	- -	- -	- -	- -	0.08 -	0.00 -	10.20 ±0.06	0.07 -	3.25 ±0.14	0.15 -	0.31 -	0.03 ±0.02	0.00 -
4 Mayonnaise	0.00 ±0.37	0.00 ±0.01	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -	0.00 ±0.02	0.00 -	5.89 0.09	0.00 -	3.19 ±0.04	0.00 -	0.42 -	0.00 ±0.01	0.00 ±0.01
5 Margarine	0.00 ±0.14	0.11 ±0.01	0.65 -	0.03 -	0.00 -	0.00 -	0.00 -	0.51 -	0.11 ±0.01	19.53 ±0.42	0.14 ±0.01	6.98 ±0.20	0.00 ±0.41	3.77 -	0.00 -	0.00 -
6 Cow milk, whole	0.00 -	1.10 ±0.02	1.06 ±0.03	2.77 ±0.05	0.04 ±0.01	3.43 ±0.04	0.11 -	12.27 ±0.04	1.07 ±0.01	35.26 ±0.18	0.56 ±0.02	13.20 ±0.03	0.11 -	0.02 -	0.04 ±0.02	0.04 -
7 Cow milk, reduced fat	0.00 -	4.16 ±0.55	0.00 -	2.45 ±0.25	0.00 -	4.52 ±1.05	0.00 -	9.68 ±0.75	0.00 -	29.68 ± 2.20	0.00 -	16.76 ±2.35	0.00 -	0.00 -	0.00 -	0.00 -
8 Butter	0.00 ±0.09	1.12 ±0.01	1.10 ±0.02	3.05 ±0.11	0.07 ±0.01	3.79 ±0.12	0.12 -	12.65 ±0.22	1.07 ±0.03	33.67 ±0.42	0.52 ±0.02	12.22 ±0.39	0.13 ±0.01	0.02 -	0.00 -	0.00 -
9 Yogurt, whole milk	0.00 -	1.15 ±0.05	1.11 ±0.03	2.95 ±0.06	0.06 -	3.60 ±0.01	0.12 -	12.29 ±0.05	1.03 ±0.01	33.75 ±0.21	0.51 ±0.02	14.70 ±0.31	0.09 -	0.03 -	0.00 -	0.00 -
10 Mozzarella cheese, whole milk	0.00 -	1.54 ±0.04	1.39 ±0.01	3.47 ±0.02	0.04 -	4.10 ±0.02	0.11 -	15.93 ±0.05	1.49 ±0.01	45.97 ±0.26	0.87 -	17.82 ±0.12	0.00 -	0.06 -	0.04 ±0.01	0.03 ±0.05
11 Paraguayan cheese, whole milk	0.00 -	1.29 ±0.08	1.21 ±0.05	3.15 ±0.09	0.05 -	3.66 ±0.08	0.11 ±0.01	12.49 ±0.04	0.97 ±0.03	33.38 ±0.14	0.45 ±0.02	14.51 ±0.16	0.09 -	0.06 -	0.02 ±0.01	0.06 ±0.01
12 Beef	0.00 ±0.13	0.04 ±0.01	0.00 -	0.00 -	0.00 -	0.07 ±0.01	0.01 -	2.84 ±0.03	0.57 ±0.01	23.83 ±0.20	0.99 -	16.99 ±0.10	0.18 ±0.02	0.00 -	0.00 -	0.00 -
13 Chicken meat	0.00 ±0.46	0.17 ±0.02	0.00 -	0.00 -	0.00 -	0.05 ±0.01	0.00 -	0.53 ±0.04	0.12 -	19.73 ±0.49	0.17 ±0.01	7.03 ±0.17	0.00 -	3.17 -	0.00 ±0.32	0.00 -
14 Raw eggs	0.00 -	0.10 ±0.08	0.00 ±0.05	0.00 ±0.09	0.00 -	0.05 0.08	0.00 ±0.01	0.43 ±0.04	0.10 ±0.03	26.91 ±0.14	0.16 ±0.02	7.72 ±0.16	0.00 -	1.74 -	0.00 ±0.01	0.00 ±0.01
15 Sausages	0.00 -	0.05 ±0.01	0.06 ±0.01	0.07 ±0.01	0.00 -	0.09 ±0.01	0.00 -	1.79 ±0.06	0.26 ±0.01	24.25 ±0.34	0.59 ±0.01	12.13 ±0.27	0.40 ±0.02	0.00 -	0.00 -	0.00 -
16 Ham	0.00 -	0.00 -	0.00 -	0.08 ±0.01	0.00 -	0.09 ±0.01	0.00 -	1.13 ±0.04	0.06 ±0.01	23.46 ±0.25	0.23 ±0.01	11.05 ±0.18	1.73 ±0.11	0.00 -	0.00 -	0.00 -
17 Hot dog	0.00 -	0.00 -	0.00 -	0.06 -	0.00 -	0.10 ±0.06	0.00 -	1.22 ±0.04	0.12 -	24.04 ±0.13	0.36 -	10.46 ±0.14	0.00 -	0.00 ±0.01	0.11 -	0.00 -
18 Red bean	0.00 -	1.15 ±0.16	0.48 ±0.05	0.00 -	0.16 ±0.03	0.16 ±0.03	0.00 -	0.31 ±0.06	0.23 ±0.03	22.27 ±0.07	0.32 ±0.08	4.76 ±0.12	0.00 -	2.24 -	0.00 ±0.05	1.11 ±0.06
19 Avocado	0.00 ±1.14	0.23 ±0.01	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -	0.15 ±0.02	0.00 -	27.41 ±0.73	0.00 -	1.21 ±0.06	0.00 -	0.00 -	0.00 -	0.00 -
20 Olive	0.00 ±0.60	0.05 ±0.01	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -	0.05 ±0.01	0.00 -	13.50 ±0.15	0.10 ±0.01	2.04 ±0.08	0.00 -	0.07 -	0.00 -	0.07 ±0.01
21 Peanut	0.00 ±0.01	0.09 ±0.02	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -	0.03 ±0.01	0.02 -	10.64 ±0.07	0.06 -	3.53 ±0.04	0.00 -	2.29 -	0.02 ±0.11	0.96 ±0.04

...continued table 2.

#Samples	C4:0	C6:0	C8:0	C10:0	C11:0	C12:0	C13:0	C14:0	C15:0	C16:0	C17:0	C18:0	C20:0	C21:0	C22:0	C24:0
22 Mbeyu	0.00 -	0.20 ± 0.01	0.18 -	0.46 -	0.01 -	0.57 ± 0.01	0.02 -	2.20 ± 0.02	0.22 ± 0.01	17.42 0.10	0.19 ± 0.01	9.54 ± 0.22	0.02 -	0.35 -	0.00 ± 0.02	0.14 ± 0.01
23 Cheese bread	0.00 -	0.62 ± 0.05	0.57 ± 0.05	1.43 ± 0.10	0.00 -	1.72 0.11	0.04 ± 0.01	5.96 0.32	0.55 ± 0.02	25.88 ± 0.31	0.38 ± 0.02	16.18 ± 0.28	0.17 ± 0.01	0.00 -	0.00 -	0.00 ± 0.02
24 Tortilla	0.00 ± 0.12	0.00 ± 0.02	0.12 ± 0.02	0.30 ± 0.03	0.00 -	0.39 ± 0.01	0.00 -	0.00 -	0.21 ± 0.01	14.42 ± 0.28	0.18 -	6.28 ± 0.72	0.00 -	0.40 -	0.00 ± 0.01	0.17 ± 0.01
25 Noodle	0.00 ± 0.28	1.07 ± 0.09	0.00 -	0.15 -	0.00 -	0.22 ± 0.02	0.00 -	0.32 ± 0.08	0.20 -	20.10 ± 1.91	0.21 0.02	4.35 ± 0.44	0.00 -	0.22 -	0.00 ± 0.02	0.21 ± 0.02
26 Chipa	0.00 ± 0.05	0.41 ± 0.03	0.37 ± 0.01	0.92 ± 0.01	0.00 -	1.23 ± 0.20	0.03 ± 0.01	4.36 ± 0.11	0.45 ± 0.01	15.78 ± 0.05	0.25 ± 0.01	6.41 ± 0.01	0.07 ± 0.01	0.28 -	0.00 -	0.13 -
27 Reviro	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -	0.13 ± 0.02	0.00 -	8.36 ± 0.13	0.00 -	4.38 ± 0.10	0.00 -	0.78 -	0.00 ± 0.04	0.33 ± 0.02
28 Sopa Paraguaya	0.00 ± 1.26	0.36 ± 0.04	0.33 ± 0.05	0.74 ± 0.03	0.00 -	0.91 ± 0.05	0.00 -	3.04 ± 0.16	0.28 -	17.30 ± 0.22	0.19 -	6.43 ± 0.05	0.56 ± 0.05	0.14 -	0.00 ± 0.01	0.00 -
29 Empanada, fried	0.00 -	0.06 ± 0.04	0.00 -	0.05 ± 0.02	0.00 -	0.09 ± 0.03	0.00 -	0.51 ± 0.05	0.08 ± 0.02	14.82 ± 0.12	0.15 ± 0.01	7.21 ± 0.17	0.30 ± 0.11	0.21 -	0.00 ± 0.01	0.00 -
30 Chipa guazú	0.00 -	0.37 ± 0.02	0.34 ± 0.02	0.78 -	0.07 ± 0.01	0.98 ± 0.01	0.03 -	3.97 -	0.53 ± 0.05	25.64 ± 0.43	0.36 ± 0.03	14.69 ± 1.18	0.16 ± 0.04	0.00 -	0.00 -	0.19 -
31 Mixto	0.00 ± 0.15	0.38 ± 0.05	0.11 -	0.31 ± 0.03	0.04 -	0.40 ± 0.01	0.00 -	1.61 -	0.22 ± 0.01	14.50 ± 0.42	0.20 ± 0.03	6.34 ± 0.71	0.02 -	0.42 -	0.00 -	0.17 -
32 Tenderloin sandwich	0.00 -	0.00 ± 0.02	0.21 ± 0.01	0.55 ± 0.02	0.00 -	0.67 ± 0.05	0.03 -	2.58 ± 0.05	0.31 -	18.94 ± 0.11	0.31 ± 0.01	8.22 ± 0.11	0.00 -	0.09 -	0.00 ± 0.01	0.10 -

among the acids present in foods of plant origin or among the foods that were prepared using vegetable oil. The content of this PUFA (linoleic acid) in sunflower oil, soybean oil, and in mayonnaise was found to be superior to 53.0% (Table 2 and Figure 1); this amount is in agreement with the value reported by other studies published in the literature²⁰.

Among the monounsaturated fatty acids (MUFAs), the acid that presented the highest concentration in all the samples was oleic fatty acid (18:1n-9c). The foods that presented the highest concentration of oleic fatty acid were olives (71.7%) and chipa (62.7%) (Figure 1 and Table 3). Chipa samples evaluated in this study contained information about the mode of preparation which included the addition of oleic acid, which is common in Paraguay. Traditionally, chipa is prepared using 50.0% animal fat and 50.0% vegetable trans fat.

TFA 18:1n-9t and 18:2n-6t were quantified in 21 of the 32 foods investigated (Tables 3 and 4). Foods containing the highest amounts of these acids included milk-based ice cream (5.1%), chipa guazú (3.8%), and cheese bread (2.9%). The presence of TFAs in these foods can be attributed to the use of hydrogenated fats in the preparation process²¹.

The alpha-linolenic acid (18:3n-3) from omega 3 fatty acids, which is known to possess therapeutic properties¹², was found to be present in all the foods evaluated with the exception of mayonnaise, milk and noodles. The highest content of alpha-linolenic was observed in colored beans (14.6%), followed by soybeans (6.6%). The foods prepared with soybean oil, such as mbeju, tortilla, and mixto, contained significant contents of alpha-linolenic acid, approximately 3.0% (Figure 1 and Table 3).

The foods derived from dairy products presented the highest content of SFA, with concentrations above 70% in butter, mozzarella cheese and Paraguayan cheese, whole milk, and yogurt (Table 4). Whole milk had a lipid content of 6.4% while skimmed milk presented 3.5% lipid content. Both mozzarella cheese and butter presented high lipid contents of 20.3% and 52.6%, respectively; this shows that the consumption of these foods leads to the ingestion of a significant amount of SFA. It is worth pointing out that there was huge variability in terms of both the percentage of lipid content and lipid profile in the different types of cheese available in markets.

In the present study, the value obtained for the lipid content of butter was 52.6%, with TFA of 0.2% (Table 3 and 4). These values were found to differ from the values reported by other studies published in the literature. Interestingly, the values obtained for margarine in our study (80.7% and 0.1% for lipids and TFA, respectively) were found to be similar to those reported by Mereles et al.²¹ (80.3% and 1.0% for lipids and TFA, respectively).

Another study showed variations in lipid profile of cheese based on the seasons of the year and showed that factors related to the animal feeding habits, among others, can exert influence over the nutritional quality of the cheese²².

A study conducted by the Brazilian National Institute of Metrology, Quality, and Technology regulatory agency (INMETRO)²³ reported the presence of 27.7% lipids in mozzarella cheese, which consisted of 17.2% SFA, 7.0% MUFA, and 0.6% PUFA. In our study, mozzarella cheese consumed in Paraguay was 20.3% lipids, of which 92.9% was SFA, 3.3% MUFA, and 3.5% PUFA (Table 4).

Indices of nutritional quality of the foods investigated

With regard to the oils and fats group, margarine, sunflower oil and soybean oil presented n-6/n-3 ratios of about 12:1, 202:1, 8:1, respectively (Table 4). The meats group presented n-6/n-3 ratios of 3:1 and 12:1 for beef and chicken, respectively. Canned meat presented n-6/n-3 ratios between 13:1 and 20:1. Cereals, tubers and their derivatives presented n-6/n-3 ratios ranging from 8:1 to 36:1; and the n-6/n-3 ratios were found to be even higher for fast food (between 11:1 to 304:1). With the exception of beef, all the aforementioned foods presented n-6/n-3 ratios superior to the values recommended in the literature. The n-6/n-3 ratios for mayonnaise, skimmed milk, and noodles were impossible to estimate as these foods did not present any concentration of n-3; in this case, the assessment of the nutritional profile can be performed through other indices. Considering the recommended n-6/n-3 ratio of 5:1, only dairy products, beef, olive and colored beans presented values regarded ideal in terms of nutritional quality that yield health benefits.

Of all the foods investigated, mozzarella cheese presented the highest IA and IT indices: 16.7 and 14.1, respectively. For purposes of comparison, a recent study¹⁹ also found the highest IA and IT indices in cheese (3.2 and 3.8, respectively; the values they obtained were, however, significantly lower than those obtained in the present study. The other dairy products evaluated in the current study presented IA and IT values ranging between 2.3 and 3.9 due to the presence of high contents of SFA (Table 4).

With regard to the oils and fats group, the IA and IT values obtained were between 0.100 and 0.200. The meats and processed meats group presented lower IA and IT values ranging from 0.300 to 0.700 for the former, and from 0.700 to 1.50 for the latter. Cereals, tubers and derivatives had IA values ranging from 0.100 to 1.20, and IT values ranging between 0.300 and 1.90, with cheese bread having the highest IA and IT values in this group. Representative samples of the fast food group had IA values ranging from 0.200 to 0.900, and IT values ranging from 0.500 to 1.70. In this group, chipa guazú had the highest IA and IT values. The fruits and vegetables group presented similar IA and IT values ranging between 0.100 and 0.700, which are regarded ideal for the maintenance of good health (Table 4). Approximately 63.0% of the foods had IA and IT values below 1.00, while about 35.0% presented IA and IT values between 1.00 and 5.00.

Table 3. Profile of monounsaturated, polyunsaturated, and trans fatty acids (reported as %) of the lipid fraction extracted from different foods consumed in Paraguay.

#Samples	C14:1	C15:1	C16:1	C17:1	C18:1n-9t	C18:1n-9	C18:2n-6t	C18:2n-6	C18:3n-6	C18:3n-3	C20:1	C20:2	C20:3n-6	22:1n-9	C20:5n-3	C24:1	22:6n-3
1 Milk-based ice cream	0.12 ± 0.01	0.00 -	0.18 ± 0.01	0.00 -	5.06 ± 0.07	31.10 ± 0.27	0.00 -	5.11 ± 0.26	0.00 -	0.68 ± 0.04	0.12 ± 0.01	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -
2 Sunflower oil	0.00 -	0.00 -	0.09 ± 0.01	0.03 ± 0.00	0.00 -	37.21 ± 0.58	0.00 -	53.31 ± 0.61	0.00 -	0.26 ± 0.01	0.12 ± 0.00	0.00 -	0.00 -	0.00 -	0.00 -	0.16 ± 0.00	0.00 -
3 Soybean oil	0.00 -	0.00 -	0.09 ± 0.00	0.04 ± 0.00	0.00 -	22.43 ± 0.77	0.00 -	56.40 ± 0.73	0.00 -	6.63 ± 0.20	0.14 ± 0.01	0.00 -	0.00 -	0.02 ± 0.00	0.00 -	0.09 ± 0.01	0.00 -
4 Mayonnaise	0.00 -	0.00 -	0.00 ± 0.00	0.02 ± 0.01	0.00 -	29.64 ± 0.76	0.00 -	60.58 ± 0.47	0.00 -	0.00 -	0.12 ± 0.00	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -
5 Margarine	0.09 ± 0.01	0.00 -	3.01 ± 0.20	0.46 ± 0.06	0.06 ± 0.01	31.69 ± 1.60	0.07 ± 0.00	28.90 ± 0.89	0.23 ± 0.00	1.91 ± 0.04	0.19 ± 0.01	0.40 ± 0.04	0.37 ± 0.04	0.00 -	0.07 ± 0.02	0.20 ± 0.04	0.50 ± 0.09
6 Cow milk, whole	0.94 ± 0.03	0.00 ± 0.00	0.96 ± 0.03	0.00 -	0.16 ± 0.01	24.13 ± 0.07	0.04 ± 0.00	2.13 ± 0.33	0.00 -	0.43 ± 0.04	0.04 ± 0.00	0.00 -	0.07 ± 0.00	0.00 -	0.00 -	0.00 -	0.00 -
7 Cow milk, reduced fat	0.00 -	0.00 ± 0.00	0.00 -	0.00 -	0.00 -	22.77 ± 1.74	0.00 -	8.66 ± 1.09	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -
8 Butter	0.99 ± 0.02	0.00 -	1.00 ± 0.03	0.24 ± 0.01	0.13 ± 0.01	23.24 ± 0.15	0.07 ± 0.01	3.76 ± 0.54	0.03 ± 0.01	0.73 ± 0.08	0.03 ± 0.00	0.02 ± 0.02	0.09 ± 0.01	0.00 -	0.03 ± 0.01	0.00 -	0.00 -
9 Yogurt, whole milk	0.83 ± 0.02	0.00 0.01	1.53 ± 0.02	0.00 -	0.16 ± 0.01	23.23 ± 0.29	0.06 ± 0.00	2.15 ± 0.17	0.03 ± 0.00	0.50 ± 0.02	0.03 ± 0.00	0.00 -	0.09 ± 0.00	0.00 -	0.00 -	0.00 -	0.00 -
10 Mozzarella cheese, whole milk	1.17 ± 0.00	0.00 -	2.11 ± 0.02	0.00 -	0.20 ± 0.01	0.00 -	0.09 ± 0.00	2.60 ± 0.29	0.04 ± 0.00	0.74 ± 0.02	0.02 ± 0.00	0.00 -	0.07 ± 0.00	0.00 -	0.04 ± 0.00	0.00 -	0.00 -
11 Paraguayan cheese, whole milk	0.77 ± 0.02	0.00 -	1.33 ± 0.01	0.00 -	0.17 ± 0.01	23.58 ± 0.29	0.03 ± 0.00	1.86 ± 0.07	0.03 ± 0.00	0.46 ± 0.01	0.11 ± 0.01	0.00 -	0.07 ± 0.01	0.09 ± 0.00	0.00 -	0.06 -	0.00 -
12 Beef	0.70 ± 0.01	0.00 -	3.74 ± 0.04	0.00 -	0.18 ± 0.00	47.93 ± 0.10	0.07 ± 0.01	1.23 ± 0.07	0.00 -	0.44 ± 0.01	0.07 ± 0.00	0.00 -	0.04 -	0.00 -	0.04 ± 0.00	0.00 -	0.00 -
13 Chicken meat	0.10 ± 0.01	0.00 -	3.00 ± 0.20	0.00 -	0.07 ± 0.01	31.91 ± 1.60	0.00 -	29.07 ± 0.91	0.17 ± 0.00	1.90 ± 0.07	0.18 ± 0.01	0.45 ± 0.01	0.45 ± 0.02	0.00 -	0.07 ± 0.01	0.18 ± 0.00	0.55 ± 0.05
14 Raw eggs	0.10 ± 0.02	0.00 -	3.40 ± 0.01	0.00 -	0.10 ± 0.01	43.52 ± 0.29	0.00 -	14.26 ± 0.07	0.09 ± 0.00	0.37 ± 0.01	0.17 ± 0.01	0.12 -	0.14 ± 0.01	0.00 ± 0.00	0.00 -	0.00 -	0.50 -
15 Sausages	0.20 ± 0.02	0.09 -	2.68 ± 0.10	0.51 ± 0.02	0.00 -	45.11 ± 0.16	0.00 -	10.03 ± 0.36	0.00 -	0.77 ± 0.04	0.55 ± 0.02	0.34 ± 0.01	0.10 ± 0.01	0.00 -	0.00 -	0.00 -	0.00 -
16 Ham	0.00 -	0.00 0.01	2.23 ± 0.08	0.06 ± 0.00	0.08 ± 0.01	40.15 ± 0.43	0.07 ± 0.01	17.28 ± 0.25	0.06 ± 0.00	0.86 ± 0.02	0.63 ± 0.04	0.00 ± 0.01	0.22 ± 0.02	0.00 -	0.00 -	0.00 -	0.00 -

...continued table 3.

#Samples	C14:1	C15:1	C16:1	C17:1	C18:1n-9t	C18:1n-9	C18:2n-6t	C18:2n-6	C18:3n-6	C18:3n-3	C20:1	C20:2	C20:3n-6	22:1n-9	C20:5n-3	C24:1	22:6n-3
17 Hot dog	0.10 ± 0.01	0.04 0.02	2.52 ± 0.02	0.31 ± 0.01	0.06 -	42.74 ± 0.11	0.00 -	16.37 ± 0.10	0.05 -	0.94 ± 0.02	0.52 ± 0.02	0.43 ± 0.01	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -
18 Red bean	0.00 -	0.00 -	0.27 ± 0.01	0.00 -	0.00 -	18.47 ± 0.55	0.00 -	30.77 ± 1.93	0.00 -	14.65 ± 0.87	0.40 ± 0.01	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -
19 Avocado	0.00 -	0.00 -	3.08 ± 0.08	0.00 -	0.00 -	38.51 ± 1.11	0.18 ± 0.02	26.48 ± 0.56	0.00 -	1.96 ± 0.04	0.17 ± 0.01	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -
20 Olive	0.00 -	0.00 -	0.74 ± 0.00	0.16 ± 0.01	0.00 -	71.67 ± 2.10	0.00 -	7.63 ± 0.37	0.00 -	1.50 ± 0.11	0.21 ± 0.01	0.00 -	0.00 -	2.20 ± 0.91	0.00 -	0.00 -	0.00 -
21 Peanut	0.00 -	0.00 -	0.06 ± 0.01	0.03 ± 0.01	0.01 ± 0.00	46.50 ± 0.03	0.00 -	33.77 ± 0.31	0.00 -	1.28 ± 0.01	0.65 ± 0.01	0.02 ± 0.00	0.00 -	0.04 ± 0.00	0.04 ± 0.01	0.00 -	0.00 -
22 Mbeyu -	0.17 -	0.00 ± 0.01	0.47 ± 0.01	0.08 ± 0.04	1.61 0.53	29.20 ± 0.01	0.12 ± 0.20	33.85 -	0.00 ± 0.01	2.80 ± 0.01	0.15 -	0.04 -	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -
23 Cheese bread	0.42 ± 0.05	0.18 -	0.74 ± 0.03	0.14 ± 0.01	2.65 0.18	31.98 ± 0.61	0.22 ± 0.02	8.80 ± 0.05	0.00 -	1.11 ± 0.03	0.12 ± 0.01	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -
24 Tortilla	1.56 ± 0.03	0.05 -	0.40 ± 0.04	0.08 ± 0.01	0.07 ± 0.01	30.61 ± 1.42	0.07 ± 0.00	40.59 ± 0.76	0.39 ± 0.10	3.40 ± 0.30	0.25 ± 0.05	0.00 -	0.00 -	0.03 ± 0.01	0.00 -	0.00 -	0.00 -
25 Noodle	0.00 -	0.00 -	0.22 ± 0.02	0.00 -	0.00 -	0.00 -	0.00 -	71.38 ± 2.73	0.00 -	0.00 -	0.54 ± 0.06	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -
26 Chipa	0.32 -	0.00 -	0.51 ± 0.01	0.13 ± 0.00	0.06 ± 0.01	62.69 ± 1.10	0.03 ± 0.01	4.84 ± 0.39	0.00 -	0.45 ± 0.02	0.13 -	0.02 -	0.03 ± 0.01	0.00 -	0.02 -	0.04 ± 0.01	0.02 -
27 Reviro	0.00 -	0.00 -	0.17 ± 0.01	0.00 -	0.00 -	37.31 ± 1.14	0.00 -	46.57 ± 0.49	0.00 -	1.30 ± 0.02	0.23 ± 0.01	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -
28 Sopa Paraguay	0.25 ± 0.02	0.00 -	0.90 ± 0.08	0.12 ± 0.01	0.00 -	35.11 ± 1.34	0.00 -	32.19 ± 0.63	0.00 -	0.71 ± 0.03	0.12 -	0.00 -	0.00 -	0.00 -	0.00 -	0.15 ± 0.01	0.16 ± 0.01
29 Empanada, fried	0.06 ± 0.01	0.02 -	0.59 ± 0.03	0.12 ± 0.01	1.57 ± 0.02	42.08 ± 0.79	0.00 -	30.30 ± 0.35	0.15 ± 0.02	0.10 ± 0.01	1.53 ± 0.09	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -
30 Chipa guazú	0.34 ± 0.00	0.00 -	1.07 ± 0.07	0.16 ± 0.02	3.52 ± 0.03	32.43 ± 1.37	0.27 ± 0.03	12.01 ± 1.18	0.00 -	1.10 ± 0.06	0.15 ± 0.00	0.00 -	0.26 ± 0.07	0.00 -	0.00 -	0.14 ± 0.01	0.00 -
31 Mixto	0.15 ± 0.01	0.00 -	0.26 ± 0.01	0.09 ± 0.01	0.07 ± 0.00	29.54 ± 0.18	0.03 ± 0.00	41.28 ± 0.73	0.47 ± 0.01	3.20 ± 0.03	0.20 ± 0.00	0.00 ± 0.00	0.00 -	0.00 -	0.00 -	0.00 -	0.00 -
32 Tenderloin sandwich	0.22 ± 0.01	0.00 -	1.17 ± 0.01	0.00 -	0.06 ± 0.01	34.11 ± 0.06	0.03 ± 0.00	30.43 ± 0.08	0.09 ± 0.00	1.64 ± 0.03	0.15 ± 0.00	0.03 ± 0.00	0.03 ± 0.00	0.00 -	0.00 -	0.00 -	0.00 -

Table 4. Indices of lipid quality of foods consumed in Paraguay.

#	Samples	Σ SFA ^a	Σ MUFA ^b	Σ PUFA ^c	Σ trans ^d	Σ n-6 ^e	Σ n-3 ^f	Σ n-6/ Σ n-3 ^g	Σ PUFA/ Σ SFA ^h	IA ⁱ	IT ^j
1	Milk-based ice cream	57.0	31.5	6.0	5.1	5.1	0.7	7.5	0.10	1.2	2.7
2	Sunflower oil	8.8	37.6	53.6	0.0	53.3	0.3	201.8	6.07	0.1	0.2
3	Soybean oil	13.9	22.8	63.0	0.0	56.4	6.6	8.5	4.52	0.1	0.2
4	Mayonnaise	9.5	29.8	60.6	0.0	60.6	0.0	-	6.38	0.1	0.2
5	Margarine	31.8	35.6	32.4	0.1	29.5	2.5	11.9	1.02	0.3	0.7
6	Cow milk, whole	71.0	26.1	2.6	0.2	2.2	0.4	-	0.04	3.1	3.9
7	Cow milk reduced fat	67.3	22.8	8.7	0.0	8.7	0.0	-	0.13	2.3	3.6
8	Butter	69.4	25.5	4.7	0.2	3.9	0.8	5.1	0.07	2.9	3.4
9	Yogurt, whole milk	71.3	25.6	2.8	0.2	2.3	0.5	4.5	0.04	3.0	3.9
10	Mozzarella cheese, whole milk	92.9	3.3	3.5	0.3	2.7	0.8	3.4	0.04	16.7	14.1
11	Paraguayan cheese, whole milk	71.4	25.9	2.4	0.2	2.0	0.5	4.3	0.03	3.1	3.9
12	Beef	45.3	52.4	1.7	0.2	1.3	0.5	2.7	0.04	0.7	1.5
13	Chicken meat	31.0	35.4	32.7	0.1	29.7	2.5	11.8	1.05	0.3	0.7
14	Raw eggs	37.2	47.2	15.5	0.1	14.5	0.9	16.6	0.42	0.5	1.0
15	Sausages	39.3	49.1	11.2	0.0	10.1	0.8	13.1	0.29	0.5	1.2
16	Ham	36.1	43.1	18.4	0.2	17.6	0.9	20.3	0.51	0.5	1.1
17	Hot dog	36.5	46.2	17.8	0.1	16.4	0.9	17.4	0.49	0.5	1.0
18	Red bean	33.2	19.1	45.4	0.0	30.8	14.6	2.1	1.37	0.4	0.4
19	Avocado	29.0	41.8	28.4	0.2	26.5	2.0	13.5	0.98	0.4	0.7
20	Olive	15.9	75.0	9.1	0.0	7.6	1.5	5.1	0.58	0.2	0.3
21	Peanut	17.6	47.3	35.1	0.0	33.8	1.3	25.6	1.99	0.1	0.3
22	Mbeyu	31.5	30.1	36.7	1.7	33.8	2.8	12.1	1.16	0.4	0.7
23	Cheese bread	53.3	33.6	10.0	2.9	8.8	1.1	7.9	0.19	1.2	1.9
24	Tortilla	22.5	33.0	44.4	0.1	41.0	3.4	12.1	1.97	0.2	0.4
25	Noodle	27.1	0.8	71.4	0.0	71.4	0.0	-	2.64	0.3	0.7
26	Chipa	30.6	63.8	5.4	0.1	4.9	0.5	10.0	0.18	0.5	0.7
27	Reviro	14.0	37.7	47.9	0.0	46.6	1.3	35.9	3.43	0.1	0.3
28	Sopa Paraguaya	29.7	36.7	33.1	0.0	32.2	0.9	37.1	1.11	0.4	0.7
29	Fried empanada	23.2	44.4	30.6	1.6	30.5	0.1	303.5	1.32	0.2	0.6
30	Chipa guazú	48.0	34.3	13.4	3.8	12.3	1.1	11.1	0.28	0.9	1.7
31	Mixto	24.7	30.2	45.0	0.1	41.8	3.2	13.0	1.82	0.3	0.5
32	Tenderloin sandwich	32.0	35.7	32.2	0.1	30.6	1.6	18.6	1.01	0.4	0.8

^a Σ SFA= total saturated fatty acid.^b Σ MUFA= total of monounsaturated fatty acid.^c Σ PUFA= total of polyunsaturated fatty acid.^d Σ trans= total of trans fatty acid (18:1n-9t and 18:2n-6t).^e Σ n-6= total of n-6 fatty acid (C18:2n-6c and C18:3n-6).^f Σ n-3= total of n-3 fatty acid (C18:3n-3 (LNA), C20:5n-3 (EPA) and DHA 22:6n-3).^g Σ n-6/ Σ n-3= ratio of omega-6 and omega-3.^h Σ PUFA/ Σ SFA= ratio of total poly-unsaturated fatty acids (Σ PUFA) and saturated fatty acids (Σ SFA).ⁱIA= atherogenicity index.^jIT= thrombogenicity index.

Figure 2: Graph of scores, PCA 2 vs. PCA 1, based on the nutritional indices.

Figure 2 shows the scores, PCA 2 vs. PCA 1, based on the nutritional indices and the sum of fatty acids present in foods consumed in Paraguay, with total variation of 93.6%. Three food groups were identified: olives and chip identified by MUFA; the dairy products group identified by the indices of thrombogenicity (IT) and atherogenicity (IA); and foods prepared by the addition of soybean oil and corn oil identified by the PUFA/SFA indices along with the n-6/n-3 ratio.

DISCUSSION

Currently, the amount of TFA recommended for ingestion is <1.0% out of the total amount of energy ingested; this is equivalent to 2.20 grams of TFA per day in a typical diet of 2,000 calories²⁴. It is worth noting that excessive consumption of TFA increases predisposition to cardiovascular diseases⁸. The food industry has been utilizing interesterified fats as substitutes for hydrogenated fats with a view toward maintaining the organoleptic properties of foods produced, particularly with regard to texture²⁵. In this context, there is an increasingly urgent need for food industry and governments worldwide to push for reformulation and prevention of the consumption of unhealthy foods and beverages, aiming at controlling obesity and the health risks posed by the consumption of these foods. Industrial TFAs promote inflammation, endoplasmic reticulum stress, and cholesterol synthesis²⁶. The National Institute of Food and Nutrition (Instituto Nacional de Alimentación y nutrición) in Paraguay has pointed to the need for a progressive reduction of industrial TFAs up to 2% total lipid²⁷. A more restrictive global agenda aims eliminate industrial TFA in 2020-2025²⁸. REPLACE²⁴, the WHO action

package set, for example, emphasizes the importance of the banning of partially hydrogenated oils, the main source of industrial trans fat.

Another point that deserves mentioning is that considering that there is some reasonable degree of variability in terms of the ingredients used and ways of preparation of the traditional foods investigated, one should expect differences in the lipid content of foods. For instance, one study analyzed chipas from different origins and found that the lipid content of home-made chipas was 16.4%, whereas that of commercially marketed chipas varied from 18.2% to 21.9%²¹. Another aspect that is worth mentioning is that whereas the traditionally home-made chipas contained no TFAs, the commercial ones presented TFAs ranging from 2.8% to 6.7%. In the present study, the amount of lipids found in chipa was 16.0%, with TFAs of only 0.1%; these values are quite close to the values reported by Mereles for traditionally home-made chipas produced from animal fat²¹.

According to the literature, a sufficiently adequate ingestion of n-3 fatty acids is essential for good health and for the reduction of health risks associated with the development of CVDs², diabetes^{11,29}, cancer^{11,29}, fatty liver³⁰, inflammations^{9,20}, and auto-immune diseases^{6,29}. Long chain n-3 fatty acids presents neuro-protective effects against neuro-degeneration diseases such as Alzheimer's and Parkinson's disease³¹. Excessive ingestion of n-6 fatty acids results in a higher n-6/n-3 ratio in diet, leading to health risks. Similarly, an increase in the intake of n-3 fatty acids gives rise to a lower n-6/n-3 ratio, thus helping to mitigate the health risks posed by the initial excessive intake of n-6. In general, intake of n-6 and n-3 in the ratio of 4:1 is essential to combat food-related diseases⁹.

The n-6/n-3 ratio found in table 4 shows the nutritional quality of foods. Depending on the individual, there can be a great variability in terms of food choices consumed in order to meet the recommended ratio n-6 and n-3 fatty acid intake. Based on several studies reported in the literature, the n-6/n-3 ratio ranging from 2:1 to 5:1 is recommended for the prevention and treatment of chronic diseases^{10,11,20,32}.

With regard to the n-6/n-3 ratio obtained in the present study, the foods derived from dairy products presented n-6/n-3 ratios ranging from 3:1 to 5:1. Similar values were obtained in other studies^{19,22}. In the case of mozzarella and Paraguayan cheeses, the n-6/n-3 ratio varied from 3:1 to 4:1, respectively; these values are in agreement with the results obtained in another study that found the n-6/n-3 ratios ranging from 3:1 to 4:1 for colonial cheese samples produced in Colombia²².

Reviro, sopa paraguaya, and empanada (fried pasty) presented n-6/n-3 ratios superior to 36:1. These high ratios are attributed to the presence of soybean and sunflower oils in the preparation of these foods, which tends to increase the levels of n-6 PUFA.

Foods with Σ PUFA/ Σ SFA ratio above 0.450 are considered to have satisfactory nutritional quality³³, considering the other indices of nutritional quality. Out of the 32 foods investigated, 19 presented values within the recommended Σ PUFA/ Σ SFA ratio, including pancho (Paraguayan hot-dog), mbeju, tortilla, noodles, reviro, sopa Paraguaya, empanada (fried pasty), mixto, and terderloin sandwich. In addition, colored beans, avocado, peanuts, and olives, which belong to the group of vegetables and fruits, exhibited Σ PUFA/ Σ SFA ratios regarded acceptable. With regard to traditional Paraguayan foods, chipa and chipa guazú presented Σ PUFA/ Σ SFA ratios of 0.200 and 0.300, respectively. Similarly, the dairy products group presented Σ PUFA/ Σ SFA ratios below 0.200. It is worth noting that although both omega 3 acids and omega 6 acids are PUFAs, the former act as precursors of prostaglandins, which possess anti-inflammatory properties and contribute toward the reduction of blood platelets, thus exhibiting anti-thrombogenic activity. Conversely, the presence of an excessive amount of omega 6 fatty acids in the body has been associated with the risk of developing non-communicable diseases^{9,20}.

There are some restrictions regarding the use of the Σ PUFA/ Σ SFA index; this is especially because, when employed solely, the index does not consider the presence of MUFAs in its assessment. The combination of the Σ PUFA/ Σ SFA index and the n-6/n-3 ratio helped discriminate one of the three food groups shown in figure 2.

The indices of atherogenicity and thrombogenicity are widely used for evaluating the nutritional value of the fats ingested in the body and the relationship to health¹⁹. These indices are related to the nutritional quality of lipids and the potential effects of these lipids on the development of cardiovascular diseases, and they are defined as the relation between pro-thrombogenic fatty acids (saturated) and anti-thrombogenic fatty acids (MUFAs and n-6 and

n-3 fatty acids)³⁴. Lower values of IA and IT indicate better nutritional quality of foods¹².

The IA index indicates the relation between the sum of the main saturated fatty acids and the main unsaturated fatty acids, where the saturated acids are regarded as pro-atherogenic, whereas the unsaturated acids are anti-atherogenic. The fatty acids C12:0, C14:0 and C16:0 have been found to increase cholesterol plasma levels (regarded hypercholesterolemic), particularly C14:0, while C18:0 has been shown to exhibit neutral effects with regard to cholesterol³⁵.

In this sense, foods rich in myristic acids, such as milk and its derivatives, present high IA. Foods regarded healthy, such as fish, present IA values less than 0.750. In the present study, the IT values obtained for butter, skimmed milk, and whole milk were 3.40, 3.60, and 3.90, respectively; these values are similar to those reported by Paszczyk and Łuczyńska for butter and UHT milk (the authors obtained IT value of 3.60 for both products)¹⁹.

Upon a thorough analysis of the indices investigated in this study, some food products have been found to present quite disturbing values. Among these foods, milk-based ice cream, mozzarella cheese, Paraguayan cheese, whole milk, yogurt, cheese bread, butter, and chipa guazú were found to have high contents of TFAs in their composition, apart from exhibiting higher values of n-6/n-3 acids ratio, Σ PUFA/ Σ SFA ratio, IA and IT indices regarded unacceptable by several studies reported in the literature. Some of these foods, including cheese bread and chipa guazú, need to be prepared with other vegetable oils that are relatively healthier, avoiding the use of hydrogenated fats.

With regard to the adoption of healthy preparation procedures, a positive example that deserves mentioning is chipa prepared from oleic acid (18:1n-9c) which, in spite of exhibiting a ratio of omega-6/omega-3 above the recommended level of 10:1, had Σ PUFA/ Σ SFA, IA and IT values within the recommended levels for a healthy diet.

CONCLUSION

It is clear that remarkable changes have occurred in the lipid composition and profile of food products due to the current trends in lifestyle where traditional diets rich in natural and less processed foods have been substituted for highly processed foods with high contents of fats. Considering the health risks posed by these highly processed foods, the recommendation is to avoid or minimize the intake of these foods in order to prevent or mitigate the negative effects their consumption have on population health. The evaluation of the nutritional quality of foods should not be confined to nutritional indices; this assessment should also go further into investigating and establishing possible links between the consumption of these food products and the risks the foods pose to groups of individuals who have predisposition toward the development of chronic diseases.

Data presented in this study can contribute toward the improvement of eating habits among the Paraguayan

population, as well as help combat the risk factors commonly associated with poor eating habits and chronic health issues. It is worth pointing out that this study does not recommend banning the consumption of any foods. However, we do recommend the re-adjustment of food consumption considering intake of the appropriate amount of foods and the use of suitable and less harmful fatty acids for the preparation of foods in order to reduce the health risks associated with the consumption of inappropriate amount of foods and fatty acids with low nutritional quality.

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