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Original Article

A Brazilian Total Diet Study: Evaluation of essential elements

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ABSTRACT

Total Diet Study (TDS) has been adopted worldwide and is based on the evaluation of food samples representing a Market Basket, which shows dietary habits of a large-scale population. This TDS presents results of the element concentrations, daily dietary intakes and contributions to the total daily intake of essential elements, Na, K, Ca, Fe, Zn and Cr in 30 food groups of a Market Basket of São Paulo State, Brazil. The methodology for the first Brazilian TDS for the São Paulo State population and its respective Market Basket was developed. Food consumption data and information were obtained from the National Household Food Budget Survey, *Pesquisa de Orçamentos Familiares* (POF) 2002–2003 conducted by the Brazilian Institute for Geography and Statistics, which includes 5440 foods. The selection criteria to carry out the Market Basket were the foods consumed at more than 2 g/day/person, which represented 72% of the total weight of the foods for this population. Element concentrations were determined by instrumental neutron activation analysis and ranged in mg kg^{-1} as follows: Na: 1.5–256,185; K: 0.51–532; Ca: 22–1827; Fe: 0.08–49; Zn: 0.030–98; and in μg kg^{-1} Cr: 2.6–799. The dietary intakes contributed by the Market Basket were: 1928 mg/day^{-1} Na; 861 mg/day^{-1} K; 275 mg/day^{-1} Ca; 5.70 mg/day^{-1} Fe; 4.25 mg/day^{-1} Zn and 20.7 μg/day^{-1} Cr. The observed low levels are probably due to the fact that Market Basket represented 72% of the weight of the household consumed foods. The highest contributions to the total intake of the essential elements were: salts, 78.9% of Na; breads, 36.9% of Fe and 46.4% of Cr; cereals, 18.7% of Zn; and milk/cream, 58.7% of Ca and 23.6% of K.

1. Introduction

Total Diet Study (TDS) entailing the analysis of a Market Basket (MB) is an approach adopted worldwide to estimate the daily intake of nutrients of interest by chemical analysis, for a large-scale population over a specific period of time (WHO, 1985, 1999). The MB consists of foods reflecting a defined total diet, based on amounts of food consumed, provided by representative national surveys. The type and quantities of foods, that are collected, are determined by the MB. The place of collection (retailers, kitchens, etc.) depends upon the objective of the study. The foods are collected as they are offered for acquisition and sent for preparation. The MB involves preparing food in the manner in which they would be normally consumed by the population being evaluated (table-ready) (WHO, 1985; Turrini and Lombardi-Boccia, 2002; FDA, 2008). For this reason, each MB differs considerably. Due to the fact that dietary habits vary in every country, the World Health Organization (WHO) considers that the MB is the most adequate method to assess the dietary intakes of nutrients and has been encouraging this approach (WHO, 1985, 1999, 2007).

Although Total Diet Studies have been conducted in several countries (WHO, 1999; Pennington, 2000; Ysart et al., 2000; Egan et al., 2002; Turrini and Lombardi-Boccia, 2002; WHO, 2002, 2005, 2006; FSANZ, 2003; Lombardi-Boccia et al., 2003; Leblanc et al., 2005; Munõz et al., 2005; Vannoort and Thomson, 2005; Nasreddine et al., 2006; FDA, 2008; Thomson et al., 2008), there was no TDS in Brazil, prior to this work. The main objective of this study was to estimate the food daily intake of essential elements (Na, K, Ca, Fe, Zn and Cr) from the food consumed by the population of São Paulo State, Brazil, using the TDS approach, based on the National Household Food Budget Survey, *Pesquisa de Orçamentos Familiares* (POF) 2002–2003.

The MB methodology of this TDS (Avegliano et al., 2008) was based on TDS of different countries. In this study, the instrumental neutron activation analysis (INAA) technique was successfully applied to estimate the concentrations of the following elements Na, K, Ca, Fe, Zn and Cr in food groups that compose the MB. Additionally, individual daily element intake for each element was calculated. Finally, the contribution of each food group to the total daily intake of these elements was evaluated.

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2. Materials and methods

2.1. Market Basket methodology

The methodology of this MB was based on TDS from WHO Guidelines (WHO, 1985) and TDS which have already been carried out in different countries since 1961 (WHO, 1999, 2002, 2005, 2006; Pennington, 2000; Egan et al., 2002; Turrini and Lombardi-Boccia, 2002; FSANZ, 2003; Lombardi-Boccia et al., 2003; Leblanc et al., 2005; Muñoz et al., 2005; Vannoort and Thomson, 2005; Nasreddine et al., 2006; FDA, 2008; Thomson et al., 2008). There are two different approaches for a TDS: individual and food group (WHO, 1985, 1999; Muñoz et al., 2005). In this study, the TDS was based on the food group approach. The sampling survey was comprised of 2017 households and 7009 inhabitants, 49% male and 51% female, ages varying from below 6 months to over 70 years. The survey represents a population of about 39 million inhabitants from São Paulo State (IBGE, 2004a,b).

To establish the TDS the following steps were involved: (1) food consumption data collection; (2) development of a Market Basket; (3) sampling; (4) kitchen preparation of food groups; (5) preparation of food groups for analysis.

The food consumption data source used was the National Household Food Budget Survey, POF 2002–2003 conducted by the Brazilian Institute for Geography and Statistics from July 2002 to June 2003. Data from the survey were available for each state of Brazil. Thus, for this TDS only the data from São Paulo State was used, containing 5440 foods, presented as food group classifications (IBGE, 2004a,b). The data referred to raw food consumption.

In order to develop the MB from 5440 foods, the selected foods had to be consumed more than 2 g/day/person, except for fish. This resulted in 71 foods which belonged to 30 food groups. The criterion of selection for 2 g/day/person was the limited resources for analytical procedures in the laboratory. Due to this criterion of food selection the MB contained 72% of the daily food intake for São Paulo state population. This percentage has successfully been carried out in TDS of other countries (Nasreddine et al., 2006; Thomson et al., 2008). Even though fish consumption was lower than 2 g/day, it was included in the MB since fish may contain important toxic elements, which could be useful for other future studies based on this MB. For this study the food group classification was the same as presented in the National Household Food Budget Survey (Avegliano et al., 2008; Avegliano, 2009).

The raw food samples were acquired from the restaurants of the University of São Paulo, São Paulo, Brazil, by random sampling of available foods on the collection day. The 1 kg criterion for each table-ready food group was used because this amount would be enough for the analyses. Furthermore, New Zealand's TDS (Thomson et al., 2008) had chosen the same criterion. The weights of raw food consumption data were corrected for edible portions and for the ready-to-consume foods. The foods were collected directly from the original package.

2.2. Preparation of food group samples

The food groups were prepared at the Central restaurant of University of São Paulo. The kitchen preparation of raw foods consisted of preparing ready-to-consume foods. Foods in each food group were prepared separately and mixed in the same proportions of food groups in the MB.

The kitchen procedures regarding to foods, utensils and equipment (food processors, domestic blenders) were vital to avoid contamination which might affect the amount of elements in the foods. All water used in food preparation was deionized water, and the utensils were of polyethylene or glass. The utensils were previously washed with 10% Extran® solution (Merck, Darmstadt, Germany) and deionized water.

The food preparation included: washing and rinsing with deionized water; discarding inedible portions (bone, fruit peels, etc.); chopping; blending; mixing; cooking (if necessary) and homogenizing. During the preparation, no salt, seasonings, oils, fats or any other ingredients were added. Coffee was prepared as "ready for drinking" by percolating boiling deionized water through powder coffee. After each individual food preparation, the foods of the same food group were mixed; and homogenized to compose the food groups. Each table-ready food group was homogenized separately.

The food weights from the survey data were corrected for the edible portions and for the ready-to-consume foods, resulting in the MB shown in Table 1.

After preparation of the table-ready food groups they were sent to the Neutron Activation Analysis Laboratory (LAN) of *Instituto de Pesquisas Energéticas e Nucleares*, *Comissão Nacional de Energia Nuclear*, IPEN/CNEN-SP, São Paulo, Brazil, in polyethylene containers for essential element determination.

The food groups (except oil and fat groups) were then frozen at −20 °C for at least 24 h and kept frozen until the freeze-drying process. Oils and fats were stored in a refrigerator at 4 °C.

Flour, biscuit, sugar, salt, oil and fat food groups were analyzed without freeze-drying. All the other food groups were freeze-dried for 10–15 h at −51 °C in a ModulyD Model freeze-dryer (Thermo Electron Corporation, Milford, MA, USA). After freeze-dried, the food groups were homogenized in a domestic blender with Ti blades. The 24 food groups were freeze-dried in order to obtain the samples in powder.

The moisture content of food groups was obtained weighing before and after the freeze-drying process using a UX4200H Model scale (Shimadzu Corporation, Canby, OR, USA). The residual moisture was obtained by scale Moisture Analyser MB45 (Ohaus Corporation, Pine Brook, NJ, USA).

2.3. Instrumental neutron activation analysis (INAA)

2.3.1. Preparation of Na, K, Ca, Cr, Fe and Zn standards

Standards of Na, K, Ca, Cr, Fe and Zn were prepared from appropriate dilutions of high purity standard solutions (SPEX Certiprep Inc., Metuchen, NJ, USA) with Milli-Q water 18.2 MΩ cm^{-1} (Millipore Corporation, Milford, MA, USA), with concentrations of 10,000 mg L^{-1} to Ca, Fe and K and 1000 mg L^{-1} to Na, Cr and Zn. Aliquots (25–100 μL) of these solutions were pipetted onto Whatman 40 filter paper using Eppendorf pipettes (Eppendorf AG, Hamburg, Germany) and then dried under an infrared lamp. After drying, filter papers were transferred to clean polyethylene bags previously cleaned with 10% nitric acid, analytical grade (Merck, Darmstadt, Germany) and Milli-Q water. Pipetted standards were prepared with the following masses: 992 μg/Ca, 2.48 μg/Cr, 495 μg/Fe, 990 μg/K, 12.4 μg/Na and 24.6 μg/Zn.

2.3.2. Certified reference materials

The accuracy of the results was determined using seven reference materials: Standard Reference Materials Oyster Tissue (SRM 1566b), Mussel Tissue (SRM 2976), Bovine Liver (SRM 1577b), Wheat Flour (SRM 1567), Peanut Butter (SRM 2387) and Reference Material Whole Milk Powder (RM 8435), from the National Institute of Standards and Technology (NIST), Gaithersburg, MD, USA, and Mixed Polish Herbs - (MPH2) from the Institute of Nuclear Chemistry and Technology (INCT), Warszawa, Poland.

2.3.3. Irradiation

About 150–200 mg of food group samples and 200 mg of reference materials were weighted in polyethylene bags. Sample

Table 1
Market Basket (MB) and % weight in food groups.

Food groups	Foods	Weight table-ready foods (g/day)	% weight of MB
Alcoholic beverages	Beer	17.58	2.30
Biscuits	Cookie	2.64	0.34
Breads	French loaf, sandwich loaf	42.52	5.55
Cereals	Polished rice, rice, corn	139.30	18.20
Coffee	Coffee	53.11[a]	6.94
Fats	Margarine	3.45	0.45
Flours	Cassava flour, wheat flour	11.94	1.56
Freshwater fishes	Red fish	0.24	0.03
Leafy vegetables	Lettuce, cabbage	3.15	0.41
Legumes	Black bean, bean	49.07	6.41
Milk/cream	Pasteurized milk, milk, skim milk, sterilized milk, low fat milk, whole milk, condensed milk	138.52	18.10
Non alcoholic beverages	Soft drink, coke, other coke, orange soft drink, guaraná, mineral water, fruit juice	105.26	13.75
Oils	Soy oil	20.84	2.72
Other dairy products	Yogurt	6.57	0.86
Other fruits	Apple	3.11	0.41
Other meats	sausage	3.06	0.40
Other vegetables	Onion, tomato	25.36	3.31
Pasta	Spaguetti	12.81	1.67
Pork meats	Cooked sausage	2.17	0.28
Poultry	Frozen chicken, chilled chicken, chicken breast, chicken thigh	9.20	1.20
Prime grade beef	Boneless sirloin steak, round beef, top loin steak, round steak, tip steak	6.96	0.91
Ready-made dishes	Smoked chicken	1.26	0.16
Salts	Table salt	5.93	0.77
Saltwater fishes	Sardine, haddock, white drum	0.60	0.08
Sauces	Processed tomato, tomato sauce	4.07	0.53
Standard grade beef	Brisket, rib roast, cross cut, shoulder	6.43	0.84
Sugars	Refined sugar, crystallized sugar, powdered sugar	47.10	6.15
Sweets	Ice-cream	2.88	0.38
Tropical fruits	Pineapple, dwarf banana, banana, orange, papaya, mango, watermelon	24.76	3.23
Tuberous vegetables	Potato, carrot	15.57	2.03
Total		765.5	100

[a] Ready for drinking.

food groups of oils and fats were weighted in polyethylene capsules. For irradiation, the food samples, reference materials and element standards were simultaneously submitted to a thermal neutron flux of 4.5×10^{12} n cm^{-2} s^{-1} for 8 h at the nuclear research reactor IEA-R1 of the Nuclear and Energy Research Institute, IPEN/CNEN-SP, São Paulo, Brazil.

2.3.4. Gamma spectrometry

After appropriate decay periods, γ-ray spectra of food group samples, reference material and element standards were measured using two High-purity Ge (HPGe) detectors: Model POP-TOP (EG&G Ortec, Oak Ridge, TN, USA) and GX 2020 (Canberra Industries INC, Meriden, CT, USA). These detectors were respectively coupled to an EG&G Ortec and Canberra card and associated electronics. Spectrum analysis was carried out using VISPECT software, in TURBOBASIC language.

3. Results and discussion

3.1. Analytical quality control

The reference materials were used for quality control purposes and to evaluate the effectiveness of the methodology applied. For each analytical batch of each food group a reference material with similar matrix was included. The mean value concentration and standard deviation obtained for Ca, Cr, Fe, K, Na and Zn in these reference materials were compared to certified values, as shown in Table 2. The analytical values were obtained after a correction for residual moisture, obtained according to drying instructions from the certificates.

The En normalization values (ISO, 2002) were calculated. If $0 < |En| < 2$, the result was considered satisfactory at the 95% confidence level. Obtained En values varied from −1.8 to +1.90, except for Na in the Oyster Tissue SRM 1566b. This indicated that the results were in agreement with certified values, as shown in Fig. 1.

3.2. Element results in food groups

3.2.1. Element concentrations

The mean and standard deviation values for the elements Ca, Cr, Fe, K, Na and Zn were obtained, at least, in three determinations for each food group samples. These values are presented on a dry weight basis in Table 3. Large variations for the concentration of the essential elements among the food groups were observed. In Table 4 the element concentrations are presented for the table-ready food groups. These values were obtained considering the loss of water during the freeze-drying process.

The mean element concentrations in table-ready food groups (Table 4) were: Na: 1.5 mg kg^{-1} (non-alcoholic beverages and legumes) to 256,185 mg kg^{-1} (salts); K: 0.51 mg kg^{-1} (non-alcoholic beverages) to 5322 mg kg^{-1} (prime grade beef); Ca: 22 mg kg^{-1} (fats) to 1827 mg kg^{-1} (saltwater fishes); Fe: 0.08 mg kg^{-1} (alcoholic beverages) to 49 mg kg^{-1} (breads); Zn: 0.030 mg kg^{-1} (alcoholic beverages) to 98 mg kg^{-1} (standard grade beef); Cr: 2.6 μg kg^{-1} (coffee) to 799 μg kg^{-1} (sweets).

3.2.2. Element daily dietary intakes and food group contributions

To assess the daily dietary intakes and the food group contribution of the elements it was important to know the concentration of each element in the food groups, as well as to calculate the percentage of each food group in the weight of the MB (Table 1). The significant dietary sources of the elements can be diluted by their small amount in the MB.

The average daily intake of each element was calculated by multiplying the concentration of each element in each table-ready food group by the respective weight (g/day) of food group in the MB (Table 1) and adding the products from all food groups. The results of daily dietary intakes in this study were: Na, 1928 mg day^{-1}; K, 861 mg day^{-1}; Ca, 275 mg day^{-1}; Fe, 5.70 mg day^{-1}; Cr, 20.7 μg day^{-1}; Zn, 4.25 mg day^{-1}, as shown in Table 5.

The results of daily intakes of essential elements in this study were lower than results of TDS of other countries as presented in Table 6.

The low levels of essential elements intakes presented in this TDS are probably due to the fact that MB of this study represented only 72% of the weight of the most consumed household foods of São Paulo State. Due to this some food sources of essential elements were not included in the MB. Furthermore, even though, the National Food Budget Survey is considered the most appropriate data source when a large group is evaluated, the national survey of this TDS included meals only consumed in the household. Consequently, the total weight of the MB is restricted and the food sources of essential elements are probably consumed in lower percentages.

Based on the daily intakes of element from each food group, related with the total intake of each element, the contribution of each food groups to total intake of the element was evaluated (Table 5). Thus, the contributions of the food of the MB to the intake of essential elements for the population of São Paulo State is dependent on the concentration of the element in the samples, and on the amount of each food present in the MB (Table 1). There was a great variation of Na, K, Ca, Cr, Fe and Zn intakes in the different food groups of this study, as can be seen in Table 5.

The *per capita* daily intake of Na was 1928 mg of which 1520 mg corresponds to the value which should be added to the food during

Table 2
Results for certified reference materials.

Elements	Reference Materials (mean ± standard deviation)[a]						
	Mixed Polish Herbs (INCT-MPH2)[c]	Mussel Tissue (SRM 2976)[d]	Whole Milk Powder (RM 8435)[e]	Wheat Flour (SRM 1567)[d]	Oyster Tissue (SRM 1566b)[d]	Bovine Liver (SRM 1577b)[d]	Peanut Butter (SRM 2387)[d]
Ca (mg kg^{-1})							
This study	10,918 ± 441	8120 ± 371	9454 ± 291	229 ± 19	863 ± 61	133 ± 11	412 ± 28
Certified value	10,800 ± 700	7600 ± 300	9220 ± 490	191 ± 4	838 ± 20	116 ± 4	411 ± 18
Cr (μg kg^{-1})							
This study	1762 ± 66	524 ± 41	<20	73 ± 16	601 ± 60	284 ± 50	<20
Certified value	1690 ± 130	500 ± 160	–	–	–	–	–
Fe (mg kg^{-1})							
This study	490 ± 21	172 ± 7	0.9 ± 0.1	13.4 ± 1.1	194 ± 11	190 ± 18	17.6 ± 2.4
Certified value	460[b]	171 ± 4.9	1.8 ± 1.1	14.1 ± 0.5	205.8 ± 6.8	184 ± 15	16.4 ± 0.8
K (mg kg^{-1})							
This study	18,693 ± 1502	9500 ± 700	12,147 ± 679	1208 ± 91	6334 ± 151	9287 ± 839	6338 ± 606
Certified value	19,100 ± 1200	9700 ± 500	13,630 ± 470	1330 ± 30	6520 ± 90	9940 ± 20	6070 ± 200
Na (mg kg^{-1})							
This study	357 ± 31	30,122 ± 50	3085 ± 49	6.1 ± 0.5	2871 ± 105	2085 ± 253	4796 ± 410
Certified value	350[b]	35,000 ± 100	3560 ± 400	6.1 ± 0.8	3297 ± 53	2420 ± 60	4890 ± 140
Zn (mg kg^{-1})							
This study	32 ± 1	143 ± 7	25 ± 2	10.7 ± 0.4	1457 ± 10	121 ± 4	27.9 ± 2.7
Certified value	33.5 ± 2.1	137 ± 13	28 ± 3.1	11.6 ± 0.4	1424 ± 46	127 ± 16	26.3 ± 1.1

[a] Mean ± standard deviation of four determinations.
[b] Informative value (–): no value presented, <: limit detection.
[c] INCT: Institute of Nuclear Chemistry and Technology, Warszawa, Poland; MPH2: Mixed Polish Herbs.
[d] SRM: Standard Reference Material (SRM), National Institute of Standards and Technology (NIST), Gaithersburg, MD, USA.
[e] RM: Reference Material (RM), National Institute of Standards and Technology (NIST), Gaithersburg, MD, USA.

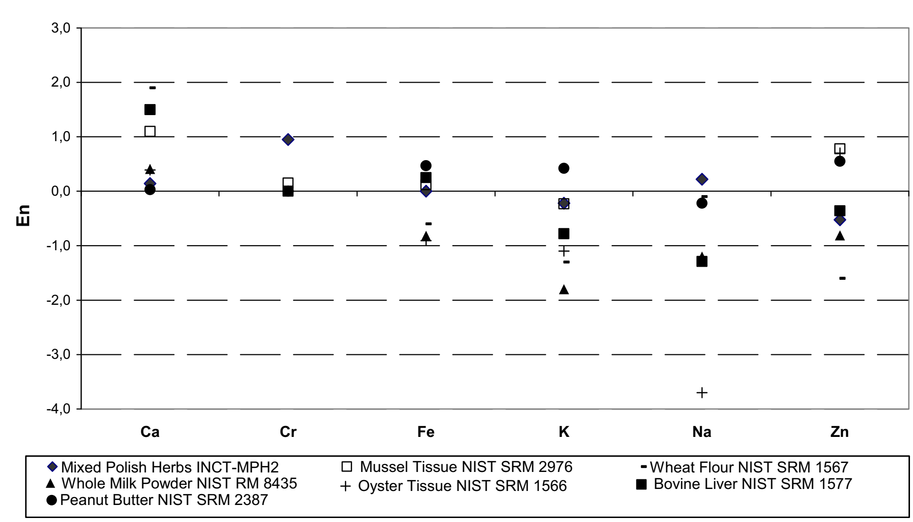

Fig. 1. En values – certified reference materials. (◆) Mixed Polish Herbs, INCT: Institute of Nuclear Chemistry and Technology, Warszawa, Poland; MPH2. (●, □, +, –, ■) SRM: Standard Reference Material (SRM), National Institute of Standards and Technology (NIST), Gaithersburg, MD, USA. (▲) RM: Reference Material (RM), National Institute of Standards and Technology (NIST), Gaithersburg, MD, USA.

Table 3
Results of element concentrations in food groups in dry weight.

Food groups	Na (mg kg^{-1a})	K (mg kg^{-1a})	Ca (mg kg^{-1a})	Fe (mg kg^{-1a})	Zn (mg kg^{-1a})	Cr (μg kg^{-1a})
Alcoholic beverages	835 ± 47 (3)	5573 ± 337 (3)	985 ± 152 (3)	2.5 ± 0.8 (3)	1.10 ± 0.07 (3)	377 ± 34 (3)
Biscuits	3494 ± 40 (2)	887 ± 52 (2)	384 ± 36 (3)	46 ± 2 (3)	9.7 ± 0.6 (3)	72 ± 10 (3)
Breads	6538 ± 769 (3)	1335 ± 252 (3)	361 ± 24 (3)	58 ± 2 (3)	14 ± 1 (3)	265 ± 38 (3)
Cereals	5.0 ± 0.9 (3)	671 ± 8 (2)	165 ± 19 (3)	2.5 ± 0.6 (3)	16 ± 1 (3)	25 ± 4 (2)
Coffee	111 ± 1 (3)	57,672 ± 520 (3)	2043 ± 230 (3)	36 ± 2 (3)	7.3 ± 0.6 (3)	88 ± 15 (2)
Fats	21 ± 1 (2)	138 ± 21 (2)	22 ± 9 (2)	5.4 ± 0.4 (2)	0.28 ± 0.02 (2)	<20
Flours	13.1 ± 0.2 (3)	2178 ± 113 (3)	573 ± 64 (3)	42 ± 5 (3)	11 ± 1 (3)	49 ± 7 (3)
Freshwater fishes	1927 ± 74 (3)	13,940 ± 780 (2)	1036 ± 73 (3)	19 ± 2 (3)	17 ± 1 (3)	50 ± 2 (2)
Leafy vegetables	620 ± 3 (2)	41,034 ± 2570 (2)	8130 ± 879 (3)	47 ± 2 (3)	34 ± 2 (3)	824 ± 18 (3)
Legumes	3.7 ± 1.0 (3)	6678 ± 397 (2)	2049 ± 245 (3)	66 ± 4 (3)	32 ± 2 (3)	23 ± 4 (2)
Milk/cream	3292 ± 148 (3)	10,841 ± 561 (3)	8631 ± 237 (3)	2.6 ± 0.9 (3)	29 ± 1 (3)	<20
Non-alcoholic beverages	26 ± 3 (2)	9.1 ± 0.6 (2)	<90	<0.30	<0.02	<20
Oils	0.9 ± 0.4 (2)	<5	<60	3.1 ± 0.3 (2)	<0.02	<20
Other dairy products	1530 ± 51 (3)	5966 ± 308 (3)	5322 ± 396 (3)	2.1 ± 0.1 (2)	16 ± 1 (3)	113 ± 19 (2)
Other fruits	24 ± 1 (2)	5676 ± 115 (2)	396 ± 12 (3)	8.1 ± 0.8 (3)	3.5 ± 0.5 (3)	83 ± 10 (2)
Other meats	14,067 ± 358 (2)	5550 ± 88 (2)	544 ± 89 (3)	28 ± 4 (3)	58 ± 4 (3)	149 ± 45 (3)
Other vegetables	446 ± 15 (2)	28,990 ± 375 (2)	2843 ± 108 (3)	35 ± 2 (3)	19 ± 1 (3)	75 ± 20 (2)
Pasta	320 ± 17 (2)	460 ± 7 (2)	351 ± 4 (3)	67 ± 2 (3)	7.3 ± 0.3 (3)	61 ± 1 (2)
Pork meats	24,188 ± 4156 (3)	1748 ± 226 (2)	2032 ± 180 (3)	47 ± 3 (3)	29 ± 1 (3)	281 ± 38 (3)
Poultry	1950 ± 190 (3)	8211 ± 805 (3)	303 ± 21 (3)	23 ± 1 (3)	58 ± 5 (3)	156 ± 10 (2)
Prime grade beef	2240 ± 15 (2)	10,992 ± 1133 (2)	294 ± 79 (2)	61 ± 2 (4)	125 ± 2 (3)	116 ± 21 (3)
Ready-made dishes	2203 ± 191 (3)	8651 ± 295 (3)	271 ± 30 (2)	20 ± 1 (3)	42 ± 4 (3)	62 ± 11 (2)
Salts	256,160 ± 6846 (2)	<2006	<820	6 ± 2 (2)	<0.02	<20
Saltwater fishes	7373 ± 266 (3)	10,904 ± 630 (3)	7045 ± 515 (3)	38 ± 1 (3)	32 ± 1 (3)	98 ± 5 (2)
Sauces	36,303 ± 1437 (3)	24,330 ± 2481 (2)	1273 ± 86 (3)	57 ± 4 (2)	11.1 ± 0.4 (3)	446 ± 96 (3)
Standard grade beef	3106 ± 329 (3)	8507 ± 552 (3)	281 ± 86 (3)	72 ± 5 (3)	206 ± 7 (3)	231 ± 21 (2)
Sugars	25 ± 1 (3)	63 ± 1 (2)	105 ± 4 (3)	1.4 ± 0.3 (2)	0.25 ± 0.02 (2)	44 ± 6 (3)
Sweets	1630 ± 133 (3)	5592 ± 270 (3)	4337 ± 556 (3)	100 ± 10 (3)	12.8 ± 0.3 (3)	2061 ± 21 (3)
Tropical fruits	18 ± 2 (3)	10,399 ± 1088 (3)	830 ± 41 (3)	12 ± 2 (3)	7.3 ± 0.4 (2)	110 ± 28 (2)
Tuberous vegetables	95 ± 5 (3)	20,933 ± 443 (3)	830 ± 25 (3)	26 ± 1 (3)	21 ± 1 (3)	35 ± 8 (3)

[a] Mean ± standard deviation.
( ): number of determinations; <: limit of detection.

Table 4
Element concentrations in table ready food groups.

Food groups	Na (mg kg^{-1a})	K (mg kg^{-1a})	Ca (mg kg^{-1a})	Fe (mg kg^{-1a})	Zn (mg kg^{-1a})	Cr (μg kg^{-1a})
Alcoholic beverages	26 ± 2 (3)	172 ± 10 (3)	30 ± 5 (3)	0.08 ± 0.02 (3)	0.030 ± 0.001 (3)	12 ± 1 (3)
Biscuits	3574 ± 49 (2)	907 ± 53 (2)	393 ± 37 (3)	47 ± 2 (3)	9.9 ± 0.6 (3)	74 ± 10 (3)
Breads	5561 ± 654 (3)	1136 ± 214 (3)	307 ± 20 (3)	49 ± 2 (3)	11.9 ± 0.9 (3)	225 ± 32 (3)
Cereals	1.8 ± 0.3 (3)	236 ± 2 (2)	58 ± 7 (3)	0.9 ± 0.2 (3)	5.7 ± 0.4 (3)	9 ± 1 (2)
Coffee	3.29 ± 0.03 (3)	1710 ± 15 (3)	61 ± 7 (3)	1.07 ± 0.06 (3)	0.22 ± 0.02 (3)	2.6 ± 0.4 (2)
Fats	21 ± 1 (2)	138 ± 21 (2)	22 ± 9 (2)	5.4 ± 0.4 (2)	0.28 ± 0.02 (2)	<20
Flours	13.9 ± 0.2 (3)	2315 ± 120(3)	609 ± 68 (3)	45 ± 5 (3)	12 ± 1 (3)	52 ± 7 (3)
Freshwater fishes	424 ± 16 (3)	3069 ± 172 (2)	228 ± 16 (3)	4.2 ± 0.4 (3)	3.7 ± 0.2 (3)	11.0 ± 0.4 (2)
Leafy vegetables	36.0 ± 0.2 (2)	2385 ± 149(2)	473 ± 51 (3)	2.7 ± 0.1 (3)	2.0 ± 0.1 (3)	48 ± 1 (3)
Legumes	1.5 ± 0.4 (3)	2635 ± 157 (2)	809 ± 97 (3)	26 ± 2 (3)	12.6 ± 0.8 (3)	9 ± 2 (2)
Milk/cream	445 ± 20 (3)	1465 ± 76 (3)	1166 ± 32 (3)	0.4 ± 0.1 (3)	3.9 ± 0.1 (3)	<2.6
Non-alcoholic beverages	1.5 ± 0.2 (2)	0.51 ± 0.03 (2)	<5.1	<0.02	<0.001	<1.1
Oils	0.9 ± 0.4 (2)	<5	<60	3.1 ± 0.3 (2)	<0.02	<20
Other dairy products	329 ± 11 (3)	1281 ± 66 (3)	1143 ± 85 (3)	0.45 ± 0.02 (2)	3.4 ± 0.2 (3)	24 ± 4 (2)
Other fruits	4.5 ± 0.2 (2)	1059 ± 22 (2)	74 ± 2 (3)	1.5 ± 0.2 (3)	0.65 ± 0.09 (3)	16 ± 2 (2)
Other meats	6734 ± 171 (2)	2657 ± 42 (2)	260 ± 43 (3)	13 ± 2 (3)	28 ± 2 (3)	71 ± 21 (3)
Other vegetables	36 ± 1 (2)	2319 ± 30(2)	227 ± 9 (3)	2.8 ± 0.2 (3)	1.52 ± 0.08 (3)	6 ± 2 (2)
Pasta	101 ± 5 (2)	146 ± 2 (2)	111 ± 1 (3)	21.2 ± 0.6 (3)	2.3 ± 0.1 (3)	19.3 ± 0.3 (2)
Pork meats	10101 ± 1736 (3)	730 ± 94(2)	849 ± 75 (3)	20 ± 1 (3)	12.1 ± 0.4 (3)	117 ± 16 (3)
Poultry	695 ± 68 (3)	2926 ± 287 (3)	108 ± 8 (3)	8.2 ± 0.4 (3)	21 ± 2 (3)	60 ± 4 (2)
Prime grade beef	1085 ± 7 (2)	5322 ± 549 (2)	142 ± 38 (4)	30 ± 1 (3)	61 ± 1 (3)	56 ± 10 (3)
Ready-made dishes	892 ± 77 (3)	3501 ± 119 (3)	110 ± 12 (2)	8.1 ± 0.4(3)	17 ± 2 (3)	25 ± 5 (2)
Salts	256185 ± 6847 (2)	<2006		6 ± 2 (2)	<0.02	<20
Saltwater fishes	1912 ± 69 (3)	2827 ± 163 (3)	1827 ± 134 (3)	9.9 ± 0.3(3)	8.3 ± 0.3(3)	25 ± 1 (2)
Sauces	5542 ± 219 (3)	3714 ± 379 (2)	195 ± 13 (3)	8.7 ± 0.6 (2)	1.69 ± 0.06 (3)	68 ± 15 (3)
Standard grade beef	1478 ± 157 (3)	4049 ± 263 (3)	134 ± 41 (3)	34 ± 3 (3)	98 ± 3 (3)	110 ± 10 (2)
Sugars	25 ± 1 (3)	63 ± 1 (2)	106 ± 4 (3)	1.4 ± 0.3 (2)	0.25 ± 0.02 (2)	44 ± 6 (3)
Sweets	632 ± 52 (3)	2167 ± 105 (3)	1681 ± 220 (3)	39 ± 4 (3)	5.0 ± 0.1 (3)	799 ± 8 (3)
Tropical fruits	4.0 ± 0.5 (3)	2334 ± 244 (3)	186 ± 9 (3)	2.7 ± 0.5 (3)	1.64 ± 0.09 (2)	25 ± 6 (2)
Tuberous vegetables	16.0 ± 0.9 (3)	3532 ± 75 (3)	140 ± 4 (3)	4.4 ± 0.2 (3)	3.5 ± 0.2 (3)	6 ± 1(3)

[a] Mean ± standard deviation.
<: Limit of detection.

cooking and at table as table salt. This value was determined in the salt food group (Table 5). Thus, in this TDS, about 21% of the ingested Na was naturally present in the foods and 78.9% corresponded to the table salt. This value (21%) obtained is higher than in the 2003/2004 New Zealand TDS, in which the naturally present Na in the foods contributed 10–15% for the total daily intake (Thomson et al., 2008).

In this TDS, the bread food group was the main source for Na from the foods (12.3%) of the MB, excluding the salt food group (Table 5).

Although sauce, other meat and pork meat food groups presented high Na levels (Table 4), these groups contributed only with 3.38% of the daily intake of Na (Table 5) and their participation in the MB was only 1.21% of the total weight (Table 1).

Table 5
Mean daily intakes (mg/person/day and μg/person/day) of essential elements and contribution (%)to the total intake of the table ready Market Basket (MB) food groups.

Food groups	Na (mg day^{-1a})	K (mg day^{-1a})	Ca (mg day^{-1a})	Fe (mg day^{-1a})	Zn (mg day^{-1a})	Cr (μg day^{-1a})
Alcoholic beverages	0.45 ± 0.03 (0.023)	3.02 ± 0.2 (0.35)	0.53 ± 0.08 (0.19)	0.001 ± 0.0004 (0.024)	– –	0.20 ± 0.02 (0.99)
Biscuits	9.4 ± 0.1 (0.49)	2.4 ± 0.1 (0.28)	1.0 ± 0.1 (0.38)	0.12 ± 0.01 (2.2)	0.030 ± 0.002 (0.62)	0.19 ± 0.03 (0.94)
Breads	237 ± 28 (12.3)	48 ± 9 (5.6)	13.1 ± 0.9 (4.8)	2.1 ± 0.1 (36.9)	0.51 ± 0.04 (11.9)	9.6 ± 1.4 (46.4)
Cereals	0.24 ± 0.04 (0.013)	32.8 ± 0.4 (3.8)	8.1 ± 0.9 (2.9)	0.12 ± 0.03 (2.1)	0.79 ± 0.05 (18.7)	1.2 ± 0.2 (5.9)
Coffee	0.170 ± 0.002 (0.009)	90.8 ± 0.8 (10.5)	3.2 ± 0.4 (1.2)	0.06 ± 0.003 (1.0)	0.010 ± 0.001 (0.27)1	0.14 ± 0.02 (0.67)
Fats	0.070 ± 0.003 (0.004)	0.48 ± 0.07 (0.055)	0.08 ± 0.03 (0.028)	0.02 ± 0.001 (0.33)	0.0010 ± 0.0001 (0.023)	– –
Flours	0.170 ± 0.003 (0.009)	28 ± 1 (3.2)	7.3 ± 0.8 (2.7)	0.53 ± 0.06 (9.4)	0.14 ± 0.01 (3.3)	0.62 ± 0.09 (3.0)
Freshwater fishes	0.100 ± 0.004 (0.005)	0.73 ± 0.04 (0.084)	0.050 ± 0.004 (0.020)	0.001 ± 0.0001 (0.017)	0.0010 ± 0.0001 (0.021)	0.003 ± 0.0001 (0.013)
Leafy vegetables	0.110 ± 0.001 (0.006)	7.5 ± 0.5 (0.87)	1.5 ± 0.2 (0.54)	0.010 ± 0.0004 (0.15)	0.010 ± 0.0004 (0.15)	0.150 ± 0.003 (0.73)
Legumes	0.07 ± 0.02 (0.004)	129 ± 8 (15.0)	40 ± 5 (14.4)	1.28 ± 0.08 (22.5)	0.62 ± 0.04 (14.6)	0.45 ± 0.08 (2.2)
Milk/cream	62 ± 3 (3.2)	203 ± 11 (23.6)	161 ± 4 (58.7)	0.05 ± 0.02 (0.86)	0.54 ± 0.02 (12.8)	– –
Non alcoholic beverages	0.150 ± 0.018 (0.008)	0.050 ± 0.004 (0.006)	– –	– –	– –	– –
Oils	0.02 ± 0.01 (0.001)	– –	– –	0.06 ± 0.01 (1.1)	– –	– –
Other dairy products	2.16 ± 0.07 (0.11)	8.4 ± 0.4 (0.98)	7.5 ± 0.6 (2.7)	0.0030 ± 0.0001 (0.052)	0.020 ± 0.001 (0.53)	0.16 ± 0.03 (0.77)
Other fruits	0.010 ± 0.001 (0.001)	3.29 ± 0.07 (0.38)	0.23 ± 0.01 (0.083)	0.0050 ± 0.0005 (0.082)	0.0020 ± 0.0003 (0.04)	0.05 ± 0.01 (0.23)
Other meats	20.6 ± 0.5 (1.07)	8.1 ± 0.1 (0.95)	0.8 ± 0.1 (0.29)	0.040 ± 0.01 (0.72)	0.09 ± 0.01 (2.0)	0.22 ± 0.07 (1.1)
Other vegetables	0.90 ± 0.03 (0.047)	58.8 ± 0.8 (6.8)	5.8 ± 0.2 (2.1)	0.070 ± 0.004 (1.3)	0.040 ± 0.002 (0.91)	0.15 ± 0.04 (0.74)
Pasta	1.30 ± 0.07 (0.067)	1.87 ± 0.03 (0.22)	1.42 ± 0.02 (0.52)	0.27 ± 0.01 (4.8)	0.030 ± 0.001 (0.70)	0.250 ± 0.004 (1.2)
Pork meats	22 ± 4 (1.1)	1.6 ± 0.2 (0.18)	1.8 ± 0.2 (0.67)	0.040 ± 0.003 (0.75)	0.030 ± 0.001 (0.62)	0.26 ± 0.03 (1.2)
Poultry	6.4 ± 0.6 (0.33)	27 ± 3 (3.1)	0.99 ± 0.07 (0.36)	0.080 ± 0.003 (1.3)	0.19 ± 0.02 (4.5)	0.51 ± 0.03 (2.5)
Prime grade beef	7.65 ± 0.05 (0.39)	37 ± 4 (4.3)	1.0 ± 0.3 (0.36)	0.21 ± 0.01 (3.6)	0.42 ± 0.01 (9.9)	0.39 ± 0.07 (1.9)
Ready–made dishes	1.12 ± 0.09 (0.058)	4.4 ± 0.2 (0.51)	0.14 ± 0.02 (0.050)	0.01 ± 0 (0.18)	0.020 ± 0.002 (0.504)	0.03 ± 0.01 (0.15)
Salts	1520 ± 41 (78.9)	– –	– –	0.04 ± 0.01 (0.63)	– –	– –
Saltwater fishes	1.15 ± 0.04 (0.060)	1.7 ± 0.1 (0.19)	1.10 ± 0.08 (0.40)	0.01 ± 0.0002 (0.11)	0.010 ± 0.0002 (0.12)	0.02 ± 0 (0.074)
Sauces	22.5 ± 0.9 (1.2)	15 ± 2 (1.8)	0.79 ± 0.05 (0.29)	0.04 ± 0.002 (0.62)	0.010 ± 0.0002 (0.16)	0.28 ± 0.06 (1.3)
Standard grade beef	9.5 ± 0.9 (0.49)	26 ± 2 (3.0)	0.9 ± 0.3 (0.31)	0.22 ± 0.02 (3.9)	0.63 ± 0.02 (14.8)	0.71 ± 0.06 (3.4)
Sugars	1.18 ± 0.05 (0.061)	2.98 ± 0.05 (0.35)	5.0 ± 0.2 (1.8)	0.07 ± 0.01 (1.2)	0.010 ± 0.001 (0.28)	2.1 ± 0.3 (10.1)
Sweets	1.8 ± 0.2 (0.094)	6.2 ± 0.3 (0.73)	4.8 ± 0.6 (1.8)	0.11 ± 0.01 (2.0)	0.01 ± 0.0003 (0.34)	2.3 ± 0.02 (11.1)
Tropical fruits	0.10 ± 0.01 (0.005)	58 ± 6 (6.7)	4.6 ± 0.2 (1.7)	0.07 ± 0.01 (1.2)	0.040 ± 0.002 (0.96)	0.61 ± 0.16 (3.0)
Tuberous vegetables	0.25 ± 0.01 (0.013)	55 ± 1 (6.4)	2.18 ± 0.07 (0.79)	0.070 ± 0.003 (1.2)	0.060 ± 0.003 (1.3)	0.09 ± 0.02 (0.45)
Total	1928 ± 278 (100)	861 ± 46 (100)	275 ± 31 (100)	5.70 ± 0.44 (100)	4.25 ± 0.24 (100)	20.7 ± 1.9 (100)

[a] Mean ± standard deviation.
( ) contribution in %.

Table 6
Total dietary daily intake estimated from different Total Diet Studies (TDSs) compared to the Market Basket in the present TDS.

TDS studies	Dietary daily intake					
	Ca (mg)	Fe (mg)	Cr (μg)	K (mg)	Na (mg)	Zn (mg)
Brazilian TDS (this study)	275	5.70	20.7	861	1928	4.25
New Zealand (Thomson et al., 2008; Vannoort and Thomson, 2005)		5.8–13.3			3603	
UK (Ysart et al., 2000)			100			8.4
Italy (Lombardi-Boccia et al., 2003)	738	12.7		2913	3812	10.6
France (Leblanc et al., 2005)	721		76.9		1800–2300	8.66
USA (Egan et al., 2002)	447–917	7.9–14.8		2683	2739	

Milk/cream and legume food groups were responsible for the highest K intake of the MB (Table 5), 23.6% and 15%, respectively. Fruit and vegetable food groups, considered good sources of K, only contributed 9.39% to the MB (Table 1).

The main sources of Ca are milk and dairy products, such as yogurt and cheese. Other good sources are fruits, vegetables and fish (IOM, 1997). In this TDS, milk/cream food group represented 58.7% of the daily intake of Ca (Table 5) and 18.1% of the total weight of table-ready food groups of the MB (Table 1). Other dairy product food group presented a small consumption of 6.57 g/day (0.86% of total weight), as shown in Table 1, contributing only to 2.7% of the Ca intake (Table 5).

The legume group with 14.4% of the daily intake of Ca was another important Ca source (Table 5). Important Ca sources also include cheese and dark green vegetables such as kale, spinach and broccoli (IOM, 1997) did not appear in the MB consumption up to 2 g per day.

The Fe fortified wheat flour product food groups (breads, flours and pasta) and legume food group were the major contributors to the total intake of Fe in the MB (Table 5). This probably occurred due to the low consumption of beef, pork, fish and poultry (Table 1). Furthermore, some high-iron food sources like beef liver, and vegetables such as spinach, soybeans, lentils, and other iron-fortified foods (Wood and Ronnenberg, 2006) were not present in the MB.

The cereal food group contributed mostly to the daily intake of Zn (18.7%), according to Table 5, and was consumed in great quantities by the population as shown in Table 1 (18.2%).

The main sources of Zn, of cattle meat, poultry, fish and pork (IOM, 2001, 2006; King and Cousins, 2006) represented only 3.91% of the total weight of the MB (Table 1).

Moreover, fruits and vegetables, which are low in Zn (King and Cousins, 2006) contributed with 9.39% of the total weight of the MB (Table 1) and therefore in higher percentages than the meats. Other major sources of Zn, such as seafood, seeds, and whole grains (IOM, 2001, 2006; King and Cousins, 2006) were not present at MB.

According to Gibson and Ferguson (2008), inadequacies of dietary Fe and Zn may occur if the diet is predominantly based on vegetables and low meat consumption.

The inclusion of industrially processed foods, which can accumulate Cr during the process (IOM, 2001, 2006; Stoecker, 2006) may be contributing to the estimate intake of this element by the MB. The highest intakes of Cr were for bread, sweet and sugar food groups (Table 5). Breads represented 46.4% of the daily intake of Cr (Table 5), while representing about 5.5% of the total weight of ready-to-consume food groups of the MB (Table 1).

4. Conclusions

The instrumental neutron activation analysis was a successful method to determine the essential elements Ca, Cr, Fe, K, Na and Zn, and its effectiveness was proved by the comparison between the element values of the certified reference materials and the obtained values of this study.

The largest element concentrations and the food groups, respectively, were: Na for salts; K for prime grade beef; Ca for saltwater fish; Fe for breads; Zn for standard grade beef; and Cr for sweets.

The food groups that represented the highest contributions to the daily dietary intake were: salts, 78.9% of Na; breads, 46.4% of Cr and 36.9% of Fe; milk/cream, 58.7% of Ca, 23.6% of K; cereals, 18.7% of Zn.

Although the food groups may be considered restricted as they represent only 72% of the weight of the household consumed foods of São Paulo state, this study is important as it is first TDS in Brazil and is based on a Market Basket that uses a methodology based on a governmental national survey. This TDS is of great importance in that it included a very large population region, São Paulo state (about 39 million inhabitants). These data will be useful for additional TDS, especially if more food groups are analyzed. This, in turn, will support and improve determination of population intakes of essential elements.

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