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Total Diet Study: Mg and Mn content estimation of a Market Basket of São Paulo state (Brazil) by Instrumental Neutron Activation

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Abstract Total Diet Studies (TDS) have been carried out to estimate dietary intakes of the essential and toxic elements for a large-scale population over a specific period of time. In this study, the TDS was based on the evaluation of food representing a Market Basket (MB), which reflected the dietary habits of the São Paulo State population, corresponding to 72 % of the average food consumption for the state of São Paulo. In the present Total Diet Study, magnesium and manganese concentrations were determined in 30 of the most consumed food groups of a MB of São Paulo State, Brazil. Instrumental Neutron Activation Analysis (INAA) has been successfully used on a regularly basis in several areas of nutrition and foodstuffs. Element concentrations were determined by INAA in freeze-dried samples and ranged in mg kg^{-1}. Mg 41.4 (fats)–5287 (coffee) and Mn 0.12 (prime grade beef)–32.9 (coffee). The average daily Mg and Mn intake was calculated by multiplying the concentration of each element in each table-ready food group by the respective weight (g day^{-1}) of the food group in the MB and adding the products from all food groups. The results of daily dietary intakes in this study were: Mg 174.8 and Mn 1.34 mg day^{-1}. Theses values were lower than the adequate intake (AI) proposed by the Food and Nutrition Board of the Institute of Medicine (USA National Academy) for adults. The low levels of Mg and Mn 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.

Keywords Food intake · Magnesium · Manganese · Total Diet Study · Market Basket

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Introduction

In recent years, due to essential characteristics of the trace elements and mainly because of their nutritional role and important functions in the human organism, there has been considerable interest in determining the levels of these elements in human diets [1, 2].

In the last few years in Brazil, Neutron Activation Analysis has been successfully used for the determination of essential trace elements in diets of different population groups and consequently can supply information about the nutritional assessment of different populations. In these studies, diets were collected by the duplicate portion method, considered the most appropriate when a small group is evaluated. The subjects of the selected Brazilian population groups were pre-school children, university student, elderly adults, healthy adults and patients with chronic renal failure. The concentrations of essential elements, such as Ca, Co, Cr, K, Fe, Mn, Mg, Na, Se and Zn were determined [3–5].

While the duplicate portion approach has been considered appropriate for small groups, the Total Diet Study (TDS) entails the analysis of a Market Basket (MB) of food, which reflects an average diet of a large population over a specific period of time. Since the dietary habits are different in every country, conducting TDS in different countries is important to assess the nutritional quality of their diets. The foods should be prepared as normally consumed, analyzed individually or combined into food groups in proportions based on available consumption data [6–12].

The methodology for the first Brazilian TDS and its respective MB, for the São Paulo State population was developed [13]. This TDS methodology was based on TDS of different countries. In this study, this methodology was used to estimate the concentrations of Mg and Mn in the food groups of the MB by Neutron Activation Analysis and their average intakes in the food groups were calculated. Evaluation of the other essential elements as Na, K, Ca, Fe, Zn and Cr in this TDS has already been presented [14].

Experimental

Market basket methodology

The methodology of this MB was based on TDS from the WHO Guidelines [6] and TDS which have already been carried out in other countries since 1961 [7–12]. This TDS was based on the evaluation of food representing a MB, which showed dietary habits of the São Paulo State population, corresponding to 72 % of the average consumption food for the state of São Paulo. The sampling survey included 2,017 households and 7,009 inhabitants [15]. This current study involved essential steps to establish a TDS: (1) information about food consumption: a national household food budget survey "POF 2002–2003" conducted by the Brazilian Institute for Geography and Statistics from July 2002 to June 2003, including 5,440 foods; (2) development of a MB including 71 foods which belong to 30 food groups previously defined (Table 1). The selection criteria were the foods consumed more than 2 g/day/person; (3) sampling: the raw food samples were acquired from the restaurants of the University of São Paulo; (4) kitchen preparation of food groups: inedible portions (such as bone, fruit peels, etc.) were discarded and prepared of ready-to-consume foods; each food were individually prepared and foods of the same food group were mixed in proportions based on available consumption data. The weights of raw food consumption data were corrected for edible portions and for the ready-to-consume foods (Table 1); (5) preparation of food group for analysis: each table-ready food group was homogenized separately. The food groups, except oil, fat, salt, flour, biscuits and sugar groups, were frozen at −20 °C for at least 24 h and were then freeze-dried.

Instrumental Neutron Activation Analysis

Preparation of food group samples

The details of food group preparation have been described elsewhere [14]. For the determination of the element concentrations by INAA, the flours, biscuits, sugars, salts, oils and fats food groups were analyzed without pre-treatment. All the other food groups were freeze-dried for 10–15 h at −51 °C and 49 μbar in the Thermo Electron Corporation (ModulyD Model) freeze-dryer. After the freeze-drying process, the food samples were ground and homogenized in a domestic blender with Ti blades. These samples were then stored in pre-cleaned polyethylene vials until analysis.

For the Mg and Mn determination by INAA, about 0.100 g of the food group samples were irradiated for 20 s in a thermal neutron flux of 6.5×10^{12} n cm^{-2} s^{-1} in a pneumatic station of the nuclear research reactor IEA-R1 at IPEN-CNEN/SP. Primary Mg and Mn standards and biological certified reference materials were simultaneously irradiated with the samples for standardization and quality control purposes. Gamma ray measurements were performed using a GC2018 Canberra HPGe detector coupled to a Canberra DSA-1000 multichannel analyzer. Gamma ray spectra were collected and processed using a Canberra Genie 2000 version 3.1 spectroscopy software. Element content calculations were carried out using a Microsoft Excel spreadsheet.

Results and discussion

The validation of the analytical method applied was performed by analysis of biological reference materials Oyster Tissue SRM 1566b, Wheat Flour SRM 1567a, Whole Milk Powder RM 8435, from the National Institute of Standards and Technology (NIST-USA) and Mixed Polish Herb (MPH-2) from the Institute of Nuclear Chemistry and Technology- (INCT- Poland). The results showed good agreement with the certified values, as can be verified in Table 2.

Table 3 presents the Mg and Mn concentrations in the different food group samples of the MB. Average daily intakes of Mg and Mn from the MB, for the São Paulo State population were calculated by multiplying the individual trace element concentration in the food groups by the corresponding weight of the ready-to-consume-food groups as presented in Table 1.

The sampling population, according to "POF 2002–2003" were comprised of 7,009 individuals, 49 % male and 51 % female, ages varying from below 6 months to over 70 years.

Magnesium

Most dietary magnesium comes from vegetables, such as dark green, leafy vegetables, which are rich in magnesium. Other foods that are good sources of magnesium: fruits or

Table 1 Market Basket and % weight in the food groups

Food groups	Foods	Weight table-ready foods (g/day)	% weight of MB
Alcoholic beverages	Beer	17.58	2.30
Biscuits	Cookies	2.64	0.34
Breads	French loaf, sandwich loaf	42.52	5.55
Cereals	Polished rice, rice, corn	139.30	18.20
Coffee	Coffee[a]	53.11	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
Fruity vegetables	Onions, tomatoes	25.36	3.31
Leafy vegetables	Lettuce, cabbage	3.15	0.41
Legumes	Black beans, beans	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 drinks, coke, other cokes, orange soft drink, guaraná, mineral water, fruit juices	105.26	13.75
Oils	Soy oil	20.84	2.72
Other dairy products	Yogurt	6.57	0.86
Other fruits	Apples	3.11	0.41
Other meats	Sausages	3.06	0.40
Pasta	Spaghetti	12.81	1.67
Pork meat	Cooked sausage	2.17	0.28
Poultry	Frozen chicken, chilled chicken, chicken breasts, chicken thighs	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	Potatoes, carrots	15.57	2.03
Total		765.5	100

[a] Ready for drinking

Table 2 Certified reference materials results

Elements	Mg mg kg^{-1}		Mn mg kg^{-1}	
	This study[a]	Certified value	This study[a]	Certified value
INCT-MPH2 (MPH)	2,983 ± 297	2,920 ± 180	191 ± 16	191 ± 12
Whole milk powder RM8435	795 ± 76	814 ± 76	0.195 ± 0.035	0.17 ± 0.05
Wheat flour SRM 1567a	365 ± 45	400 ± 20	9.51 ± 0.01	9.4 ± 0.9
Oyster tissue SRM 1566b	1,382 ± 94	1,085 ± 23	18.4 ± 0.4	18.5 ± 0.2

[a] Mean and standard deviation of four determination

Table 3 Results of Mg and Mn concentrations and daily intakes of food groups

Food groups	Concentrations (mg kg^{-1} in dry weight)[a]		Daily intakes (mg day^{-1})	
	Mg	Mn	Mg	Mn
Alcoholic beverages	1,289 ± 37	1.81 ± 0.18	0.67	0.0009
Biscuits	356 ± 57	8.15 ± 0.64	0.94	0.02
Breads	559 ± 45	8.25 ± 0.04	19.2	0.28
Cereals	171 ± 9	7.0 ± 0.3	8.19	0.34
Coffee	5,287 ± 206	32.9 ± 8.0	7.89	0.05
Fats	41.4 ± 5.7	0.12 ± 0.01	0.14	0.0004
Flours	430 ± 14	14.6 ± 0.1	5.14	0.17
Freshwater fishes	2,654 ± 187	0.34 ± 0.02	0.13	0.00002
Fruity vegetables	1,370 ± 100	13.7 ± 1.9	2.59	0.03
Leafy vegetables	2,440 ± 35	18.5 ± 1.8	0.40	0.0031
Legumes	1,161 ± 205	13.6 ± 0.9	20.1	0.23
Milk/cream	733 ± 12	0.29 ± 0.01	13.1	0.005
Non-alcoholic beverages	148 ± 25	0.35 ± 0.02	0.87	0.002
Oils	na	na	–	–
Other dairy products	308 ± 5	0.31 ± 0.01	0.40	0.0004
Other fruits	246 ± 30	8.2 ± 2.6	0.13	0.005
Other meats	286 ± 68	1.39 ± 0.31	0.41	0.002
Pasta	207 ± 1	5.03 ± 0.03	0.18	0.02
Pork meats	1,860 ± 185	2.9 ± 1.1	1.60	0.0025
Poultry	434 ± 18	0.42 ± 0.09	1.35	0.0013
Prime grade beef	508 ± 74	0.12 ± 0.04	1.56	0.0004
Ready-made dishes	2,842 ± 114	0.31 ± 0.03	1.41	0.0002
Salts	na	na	–	–
Saltwater fishes	3,655 ± 401	1.58 ± 0.06	0.55	0.0002
Sauces	1,247 ± 105	11.5 ± 0.4	0.71	0.01
Standard grade beef	273 ± 69	0.22 ± 0.08	0.79	0.0006
Sugars	81.2 ± 8.8	0.13 ± 0.01	3.83	0.0061
Sweets	2,034 ± 144	3.61 ± 0.50	2.18	0.004
Tropical fruits	944 ± 146	13.6 ± 0.9	4.79	0.07
Tuberous vegetables	1,389 ± 72	8.5 ± 1.4	76.2	0.02
Total			174.8	1.34

[a] Means and standard deviation of two determinations

na not analysed

vegetables (such as bananas, dried apricots, and avocados), unpolished or unrefined or whole grains (such as brown rice and millet), nuts (such as almonds and cashews), soy products (such as soy flour and tofu), peas and beans (legumes), seeds, starches [16, 17].

In this MB, Mg concentrations ranged from 41.4 (fats) to 5,287 mg kg^{-1} (coffee). The food groups composed of tuberous vegetables showed high daily intake (76.2 mg) of this element representing 41.3 % of the total weight of ready-to-consume-food groups of this MB, followed by the legume group with daily intake of 20.1 mg (11.5 %) and the bread group with 19.2 mg day^{-1} (10.9 %). The Mg intake in other Brazilian diets varied from 122 to 133 mg day^{-1} [18]. The Mg daily intake of this MB was 174.8 mg day^{-1} representing only 42 % of the Recommended Dietary Allowance (RDA) for the male group (420 mg day^{-1}) and 55 % of the RDA for the female group (320 mg day^{-1}) [19].

Manganese

Manganese is considered an essential nutrient, since the human body requires it to function properly and is a nutrient involved in many chemical processes in the body, including processing of cholesterol, carbohydrates, and protein. It may also be involved in bone formation. Manganese is a trace element and ingesting a small amount from food or water is needed to stay healthy. This element is found in several foods including nuts, legumes, seeds, teas, whole grains, and leafy green vegetables. The primary exposure to Mn is by consuming foods or nutritional supplements containing Mn [20, 21].

Manganese concentrations in the food groups ranged from 0.12 (prime grade beef) to 18.5 mg kg^{-1} (leafy vegetables). Legumes, tropical fruits, wheat flour and fruit vegetables showed the highest Mn concentrations.

The cereal food group was the major contributor to the total intake of Mn in the MB. The Mn intake was 1.34 mg day^{-1}, representing 58.3 % of the Adequate Intake (AI) for the adult male group (2.3 mg day^{-1}) and 77.8 % for the adult female group (1.8 mg day^{-1}). This value is similar to the Italian Mn intake (1.38 mg day^{-1}). According to Bettinelli et al. [22] most data in literature concerning the habitual diets all over the word range from 0.36 to 1.78 mg Mn/day.

The daily intake values for Mg and Mn obtained through this MB were low compared with the recommended values. These results can be attributed to the limitation of this study based on the limits of the national survey. The National Food Budget Survey is considered the most appropriate data source when a large group is evaluated. However, the national survey of this TDS included meals only consumed in the household. Thus, the food consumption per capita by data from POF in Brazil was 938 g, from which only 72 % were included in the MB of this TDS. For this reason, results obtained in this study may be underestimated.

Another Brazilian study based on the same national survey (POF 2002–2003) stated that in the same way foods consumed out of the household was not considered by this type of budget survey, therefore the availability of nutrients could be higher than data of this POF, mainly for urban families [23].

Conclusions

Instrumental Neutron Activation Analysis was a successful method to determine the essential elements Mg and Mn and its effectiveness was proved by the comparison between the element values of the certified reference materials and the obtained values of this study. 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 nationwide survey.

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