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Macro and microminerals: are frozen fruits a good source?

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ABSTRACT

Fruits are rich in minerals, which are essential for a wide variety of metabolic and physiologic processes in the hum
body. The use of frozen fruits has greatly spread in the last years not only in the preparation of juices, but also as ra
material for yogurts, candies, cookies, cakes, ice creams, and children's food. However, up to now there is no da
about the mineral profile of frozen fruits. This is the first database to quantify the levels of minerals in 23 samples
frozen fruits, including the most used around the world and some native fruits from the Amazon rainforest in Braz
Considering the Dietary Reference Intakes, 100g of frozen fruits can provide 0.2 to 2.8% of macro and 2.5 to 100
of microminerals for adults (31-50 years old). Although geographical differences should be considered, these data c
help to plan diets and to develop population interventions aiming to prevent chronic diseases.

Key words: diet, dietary recommendations, Dietary Reference Intakes, frozen fruits, minerals.

INTRODUCTION

Many of the current diets are rich in fat, salt, and sugar, and poor in complex carbohydrates, vitamins and minerals, and are responsible for an increase in diet-related diseases such as obesity, diabetes, cardiovascular problems, hypertension, osteoporosis, and cancer. It is believed that the ingestion of fruits and vegetables helps to prevent these diseases. Fruits are important components of diet, responsible not only for adding a variety of color and texture to meals, but also for providing essential nutrients. Fruits are low-fat and low-calorie foods, with relatively small amounts of protein and carbohydrates. However, they are rich in fibers and add a lot of significant micronutrients to the human diet (Zhi et al.

Among the micronutrients found in fruits,
als represent a class of inorganic substances that
ent in all kinds of fruits. The human body need
twenty different minerals in order to function p
(Williams 2006). These elements can be classifi
macro and microminerals. Macro minerals are
in amounts higher than 100 mg/day and inclu
cium (Ca), phosphorus (P), magnesium (Mg), sul
sodium (Na), chloride (Cl) and potassium (K).
minerals (needed in amounts lower than 100 m
include elements such as iron (Fe), zinc (Zn), iod
selenium (Se), manganese (Mn), chromium (Cr),
(Cu), molybdenum (Mo), fluorine (F), boron (B)
(Co), silicon (Si), aluminum (Al), arsenic (Ar), t

are indispensable for the maintenance of life, growth, and reproduction (Alsafwah et al. 2007).

Nowadays, a diet that is rich in fruits is associated with a reduced risk of many diseases (Genkinger et al. 2004). However, it is difficult to find fruits *in natura* – which are perishable – during all year round and/or in places far from the harvesting field. The intake of frozen fruits has widely spread in many countries. They are easy to commercialize and are an important source of raw material. They can be used in yogurts, candies, cookies, cakes, ice creams, fresh drinks and children's food (Hassimotto et al. 2005). In a recent work (Spada et al. 2008), it was demonstrated that fruits, even frozen, are rich in carotenoids, ascorbic acid and phenolic compounds and present an important antioxidant activity. However, to our knowledge, there is no data about mineral levels in frozen fruits. Therefore, the aim of this study was to determine the mineral levels in 23 samples of frozen fruit through PIXE (Particle Induced X-ray Emission) technique. The results can be important to help the population to achieve the recommended dietary allowance (RDA) threshold for minerals.

MATERIALS AND METHODS

Frozen Fruits

Frozen pulp of acerola (*Malpighia glabra* L.), apple (*Malus domestica* B.), acai (*Euterpe oleracea* L.), black mulberry (*Morus nigra* M.), cashew apple (*Anacardium occidentale* L.), coconut (*Cocos nucifera* L.), cupuacu (*Theobroma grandiflorum* W.), kiwi fruit (*Actinidia chinensis* P.), mango (*Mangifera indica* L.), melon (*Cucumis melo* L.), papaya (*Carica papaya* L.), passion fruit (*Passiflora alata* C.), peach (*Prunus persica* L.), pineapple (*Ananas sativus* L.), raspberry (*Rubus idaeus* L.), red guava (*Psidium guajava* L.), soursop (*Annona muricata* L.), strawberry (*Fragaria vesca* L.), Surinam cherry (*Eugenia uniflora* L.), and frozen juice of red grape (*Vitis vinifera* L.), lemon (*Citrus limon* B.), orange (*Citrus aurantium* L.) and tangerine (*Citrus reticulata* L.) were obtained from the company Mais Fruta (Antonio Prado, RS, Brazil). Pulps and juices were produced with juices. With regard to red grape, lemon, orange, and tangerine juices, flesh was separated from the fluid that was obtained from pressing. Pulps and juices were divided into 100 g aliquots and kept frozen at –20°C. No organophosphorus or carbamate pesticides were detected in the samples, through assay described by Bastos et al. (1991) and de Lima et al. (1996).

Particle Induced X-ray Emission Analysis

Quantification of mineral compounds that are present in frozen fruits was carried out using PIXE. This technique has a truly multielemental capability, that is, all elements with atomic number higher than 11 can be simultaneously detected in a single measurement on the same target (Johansson et al. 1995). The sensitivity is very good (of about a few parts per million) and ranges smoothly as a function of atomic number. It is important to note that PIXE sensitivity depends on the sample being analyzed. The analysis is relatively fast and usually takes a few minutes. Since this technique is non-destructive, it preserves the original samples, allowing additional measurements if required. Sample preparation in its solid form (for a variety of samples) does not require any sophisticated handling or chemical treatment, thus drastically reducing any chance of contamination. Nowadays, PIXE is widely used to characterize a variety of materials, including biological, geological and environmental samples (Kern et al. 2005, Franke et al. 2006). For PIXE analysis, fruit samples were dried, crushed and pressed into pellets, as described by (Franke et al. 2006). Measurements were carried out at the Ion Implantation Laboratory of the Physics Institute of the Federal University of Rio Grande do Sul. A 3 MV Tandetron accelerator provided a 2 MeV proton beam with an average current of 2 nA at the targets. The characteristic X-rays induced by the proton beam were detected by a lithium doped silicon detector with an energy resolution of 155 eV at 5.9 keV, positioned at an 135° angle considering the beam direction. The data were analyzed using the GUPIX code (Maxwell et al. 1989, Campbell et al. 2000). The standardization

Statistical Analysis

Data were subjected to analysis of variance and means were compared using Tukey's *post-hoc* test using the SPSS program, version 12.0 (SPSS, Chicago, IL).

RESULTS AND DISCUSSION

This is the first work to evaluate the mineral content of 23 frozen fruits, including the most used around the world and some native fruits from the Amazon rainforest in Brazil. Frozen fruits are used not only in the preparation of juices, but also as raw material for yogurts, candies, cookies, cakes, ice creams, and children's food (Spada et al. 2008).

The mineral content found in fruits is presented as macro (Table I) and microminerals (Table II). The Dietary Reference Intakes (DRI), defined as the average daily intake level sufficient for meeting the nutrient requirements of nearly all – 97 to 98% – healthy individuals in a particular life stage and gender group, is also shown. Where there was insufficient scientific evidence to establish a DRI, we used the Dietary Recommendation (DR), which is the recommended average daily nutrient intake level based on observed or experimentally determined estimates nutrient intake by a group, or groups, of apparently healthy people assumed to be in an adequate nutritional state (IOM 2004). All fruits here studied had Mg, Cl, P, K and Ca. Sulfur was found in all fruits, except in cupuacu and passion fruit, native Brazilian fruits. Only coconut, lemon and papaya presented Na.

The micro mineral Fe was found in all fruits, Mn in 65.2% of them, and Cu and Zn in 30.4% of the analyzed fruits. A low level of Cr was found in melon, orange and papaya. The microminerals Si and Al were found in 91.30% and 39.13% of fruits, respectively.

Macro minerals are essential for a wide variety of metabolic and physiologic processes in the human body. Ca, Mg, K, Na and Cl, for example, are important for many enzymatic activities, for the composition of the skeletal system, and for ATP formation (Williams 2006).

It was observed that frozen fruits (100 g) are able

hydroxyapatite crystal size, and thereby, prevent larger crystals that could lead to brittle bone (B et al. 2009).

Around 0.5% (both sexes) of the DRI for P can be supplied by 100 g of frozen fruits. C provides strength and hardness to bones and tee mediates vascular constriction and vasodilation, contraction, transmission of nerve impulses and clotting (Krall 2000). Phosphorus is also a con of bones (Bonjour et al. 2009), but when in high it could lead to Ca metabolism disorders becau drop in the plasma concentration of ionized C secondary hyperparathyroidism (Bonjour et al. 2

Chloride, potassium and sodium were fo small amounts, reaching only about 0.2% of t These minerals present important roles in the co cardiac output and peripheral vascular resistance are the main determinants of the blood pressu (Karppanen et al. 2005). Cl and Na were believe readily equilibrated and achieving iso-osmolali blood (Titze and Ritz 2009). In excess, these el can produce hyperchloraemic acidosis, renal v striction and reduced glomerular filtration rate 2004).

Frozen fruits (100 g) can provide about 3.5% and 1.5% (women) of the DRI for Fe. Acai, ap tangerine are rich in Fe, and 100 g of these froze can contribute to approximately 7% of the DRI f Red grape and coconut (100 g) can reach 22.2% Mn DRI. All fruits can provide more than 100% Cu DRI for men and women. Levels of Zn f frozen pulps are able to supply about 2% of D men and 3% for women. Microminerals such Mn, Cu and Zn are cofactors of many enzymes a of the active site of some oxidases and oxygenase liwell and Gutteridge 2007). Iron is a compo hemoglobin, myoglobin, cytochromes, and a lot zymes in the muscle cells (Donabedian 2006). ganese is a micro mineral that is found in all tissu is required for normal amino acid, lipid, prote carbohydrate metabolism (Aschner and Aschner It is also a microcomponent of metalloenzyme

TABLE I
Level of macrominerals (mg%) in frozen fruits.

Samples	Mg	Cl	P	Ca	K	S	Na
Acai	8.47 ± 0.17^{a}	1.96 ± 0.12^{a}	3.05 ± 0.07^{a}	3.50 ± 0.13^{a}	$1.03 \pm 0.40^{a*}$	1.91 ± 0.01^{a}	nd
Acerola	8.64 ± 0.22^{a}	2.38 ± 0.19^{a}	3.25 ± 0.16^{a}	5.82 ± 0.05^{b}	1.22 ± 0.50^{b}	2.17 ± 0.09^{ab}	nd
Apple	7.74 ± 0.24^{a}	2.05 ± 0.02^{a}	2.61 ± 0.14^{a}	3.60 ± 0.50^{a}	0.97 ± 0.10^{a}	1.73 ± 0.03^{a}	nd
Black mulberry	8.21 ± 0.05^{a}	2.26 ± 0.04^{a}	3.01 ± 0.42^{a}	4.83 ± 0.02^{c}	1.35 ± 0.30^{b}	1.99 ± 0.07^{a}	nd
Cashew apple	8.22 ± 0.01^{a}	2.99 ± 0.34^{b}	2.53 ± 0.47^{c}	3.49 ± 0.05^{a}	1.43 ± 0.10^{b}	1.46 ± 0.55^{a}	nd
Coconut	9.67 ± 0.24^{a}	2.60 ± 0.01^{a}	4.43 ± 0.09^{b}	7.60 ± 0.59^{d}	2.41 ± 0.16^{b}	3.59 ± 0.21^{c}	26.95 ± 1.05^{a}
Cupuacu	8.48 ± 0.02^{a}	0.23 ± 0.07^{d}	3.13 ± 0.12^{a}	6.59 ± 0.07^{d}	1.55 ± 0.07^{b}	nd	nd
Kiwi fruit	8.91 ± 0.19^{a}	2.66 ± 0.05^{b}	3.34 ± 0.01^{a}	7.03 ± 0.03^{d}	2.07 ± 0.07^{b}	2.48 ± 0.09^{b}	nd
Lemon	8.98 ± 0.15^{a}	2.73 ± 0.02^{b}	3.47 ± 0.02^{a}	7.02 ± 0.03^{d}	2.21 ± 0.53^{b}	2.23 ± 0.03^{ab}	23.15 ± 1.44^{ab}
Mango	7.62 ± 0.05^{a}	1.89 ± 0.02^{a}	2.69 ± 0.07^{c}	3.43 ± 0.01^{a}	1.23 ± 0.16^{c}	1.79 ± 0.02^{a}	nd
Melon	11.15 ± 0.28^{b}	3.55 ± 0.84^{c}	4.17 ± 0.27^{b}	10.33 ± 0.36^{e}	2.22 ± 0.21^{b}	2.96 ± 0.86^{b}	nd
Orange	8.08 ± 0.02^{a}	2.16 ± 0.02^{a}	2.85 ± 0.02^{c}	4.45 ± 0.02^{c}	1.49 ± 0.02^{c}	1.87 ± 0.07^{a}	nd
Papaya	8.44 ± 0.49^{a}	1.82 ± 0.13^{a}	2.96 ± 0.02^{c}	5.32 ± 0.04^{c}	1.55 ± 0.26^{b}	2.01 ± 0.07^{a}	21.80 ± 1.02^{b}
Passion fruit	8.44 ± 0.23^{a}	2.36 ± 0.02^{a}	1.26 ± 0.07^{d}	5.42 ± 0.09^{c}	1.21 ± 0.16^{c}	nd	nd
Peach	11.32 ± 0.34^{b}	3.68 ± 0.06^{c}	3.91 ± 0.26^{a}	5.58 ± 0.06^{c}	1.53 ± 0.21^{c}	2.57 ± 0.05^{b}	nd
Pineapple	8.40 ± 0.33^{a}	2.30 ± 0.17^{a}	3.12 ± 0.09^{a}	4.57 ± 0.24^{c}	1.34 ± 0.52^{c}	2.01 ± 0.06^{a}	nd
Raspberry	8.40 ± 0.09^{a}	2.20 ± 0.02^{a}	3.10 ± 0.01^{a}	4.48 ± 0.25^{c}	1.52 ± 0.18^{c}	1.97 ± 0.02^{a}	nd
Red grape	8.14 ± 0.23^{a}	1.94 ± 0.01^{a}	2.81 ± 0.08^{c}	3.25 ± 0.26^{a}	0.90 ± 0.30^{a}	1.77 ± 0.06^{a}	nd
Red guava	8.61 ± 0.14^{a}	2.55 ± 0.02^{a}	3.16 ± 0.05^{a}	6.09 ± 0.09^{d}	14.4 ± 0.50^{b}	2.24 ± 0.06^{ab}	nd
Soursop	8.48 ± 0.61^{a}	2.36 ± 0.31^{a}	3.21 ± 0.10^{a}	5.72 ± 0.15^{c}	1.09 ± 0.20^{b}	2.19 ± 0.05^{ab}	nd
Strawberry	9.15 ± 0.08^{a}	2.69 ± 0.03^{b}	3.40 ± 0.04^{a}	6.57 ± 0.15^{d}	1.61 ± 0.42^{b}	2.21 ± 0.03^{ab}	nd
Surinam cherry	8.57 ± 0.14^{a}	2.12 ± 0.15^{a}	3.05 ± 0.09^{a}	4.43 ± 0.06^{c}	1.38 ± 0.07^{b}	1.87 ± 0.15^{a}	nd
Tangerine	10.66 ± 0.14^{b}	3.48 ± 0.17^{c}	2.55 ± 0.07^{c}	5.40 ± 0.80^{c}	1.49 ± 0.50^{b}	2.67 ± 0.83^{b}	nd
Men/day	*420 mg*	**2300 mg**	*700 mg*	*1000 mg*	**4700 mg**	not determinable	**1500 mg**
Women/day	*320 mg*	**2300 mg**	*700 mg*	*1000 mg*	**4700 mg**	not determinable	**1500 mg**

[a]Data are mean ± SD values of three independent experiments and different letters indicate a significant difference according to analysis of variance and Tukey's *post hoc* test ($p \leq 0.05$) for each mineral evaluated. nd: not detected. This table presents *Dietary Reference Intakes (DRI)* in italics and **Dietary Recommendations** in bold type, both for adult individuals (31-50 years old).

tion, regulation of blood sugar and cellular energy, reproduction, digestion, bone growth, and it aids in defense mechanisms against free radicals (Aschner and Aschner 2005). Copper promotes the formation of the mitochondrial heme, and the reduction of erythrocyte half-life in anemia (Conrad and Umbreit 2000). Diets low in copper are suggested as an explanation for much of the epidemiology and patho-physiology of ischemic heart disease (Klevay 2000). Zinc is essential as a catalyst for regulating the activity of over 300 specific zinc-depended enzymes (McCall et al. 2000).

Chromium controls some physiological process in pulps of melon, orange and papaya (100 g) are able to provide more than 100% of the Cr DR.

Our results show the mineral profile of 23 frozen fruits, which may help to provide the flexibility needed to achieve the optimal dietary mineral content for a healthy human diet. However, it should be taken into account that the mineral content may be influenced by growing conditions, such as soil and geographical factors (Ercisli and Ohran 2007). In addition, the bioavailability of minerals seems to be dependent on cultivar, the environment and harvest year (Bohn et al. 2008). Some compounds such as ascorbic acid can help Fe absorp-

TABLE II
Level of microminerals (mg%) in frozen fruits.

Samples	Fe	Mn	Cu	Zn	Cr	Si	Al
Acai	0.51 ± 0.28^{a}*	0.27 ± 0.07^{a}	nd	0.20 ± 0.01a	nd	1.22 ± 0.03^{a}	nd
Acerola	0.26 ± 0.85^{b}	nd	nd	nd	nd	1.35 ± 0.07^{a}	nd
Apple	0.54 ± 1.32^{a}	0.29 ± 0.04^{ab}	1.80 ± 0.14^{a}	0.28 ± 0.05^{ab}	nd	1.12 ± 0.04^{a}	4.16 ±
Black mulberry	0.28 ± 0.57^{b}	0.31 ± 0.01^{b}	nd	nd	nd	1.28 ± 0.02^{a}	nd
Cashew apple	0.28 ± 0.64^{b}	nd	nd	nd	nd	1.54 ± 0.53^{a}	nd
Coconut	0.24 ± 0.42^{b}	0.40 ± 0.07^{b}	nd	nd	nd	1.60 ± 0.07^{a}	nd
Cupuacu	0.20 ± 0.19^{c}	0.20 ± 0.01^{a}	2.25 ± 0.78^{ab}	nd	nd	1.30 ± 0.06^{a}	nd
Kiwi fruit	0.21 ± 0.42^{b}	0.19 ± 0.02^{a}	nd	nd	nd	nd	nd
Lemon	0.27 ± 0.85^{b}	0.21 ± 0.06^{a}	2.30 ± 0.42^{b}	0.26 ± 0.04^{ab}	nd	1.37 ± 0.07^{a}	5.35 ±
Mango	0.18 ± 0.76^{c}	0.17 ± 0.06^{a}	1.85 ± 0.35^{a}	0.21 ± 0.03^{a}	nd	1.11 ± 0.01^{a}	4.17 ±
Melon	0.28 ± 0.07^{b}	0.31 ± 0.04^{b}	nd	nd	0.15 ± 0.01^{a}	1.66 ± 0.60^{a}	nd
Orange	0.28 ± 0.92^{b}	0.18 ± 0.01^{a}	nd	0.30 ± 0.08^{ab}	0.13 ± 0.02^{a}	1.22 ± 0.02^{a}	4.47 ±
Papaya	0.16 ± 0.28^{c}	nd	2.05 ± 0.07^{c}	0.22 ± 0.01^{a}	0.18 ± 0.04^{b}	1.31 ± 0.07^{a}	4.72 ±
Passion fruit	0.16 ± 0.07^{c}	0.20 ± 0.04^{a}	1.55 ± 0.05^{a}	0.30 ± 0.01^{b}	nd	1.26 ± 0.04^{a}	4.73 ±
Peach	0.34 ± 0.27^{b}	nd	nd	nd	nd	1.74 ± 0.07^{a}	nd
Pineapple	0.30 ± 0.56^{b}	0.30 ± 0.06^{b}	nd	nd	nd	1.25 ± 0.06^{a}	nd
Raspberry	0.25 ± 0.42^{b}	0.21 ± 0.05^{a}	nd	nd	nd	1.29 ± 0.07^{a}	nd
Red grape	0.18 ± 0.07^{c}	nd	3.10 ± 0.85^{c}	nd	nd	1.18 ± 0.01^{a}	4.12 ±
Red guava	0.18 ± 0.02^{c}	0.14 ± 0.02^{a}	nd	nd	nd	nd	nd
Soursop	0.18 ± 0.21^{c}	nd	nd	nd	nd	1.29 ± 0.06^{a}	4.83 ±
Strawberry	0.35 ± 0.78^{b}	0.28 ± 0.03^{a}	nd	nd	nd	1.39 ± 0.03^{a}	5.21 ±
Surinam cherry	0.14 ± 0.28^{c}	nd	nd	nd	nd	1.32 ± 0.04^{a}	nd
Tangerine	0.61 ± 0.21^{a}	nd	nd	nd	nd	3.82 ± 0.42^{b}	nd
Men/day	*8 mg*	*2.3 mg*	*0.9 mg*	*11 mg*	**35μg**	not determinable	not detern
Women/day	*18 mg*	*1.8 mg*	*0.9 mg*	*8 mg*	**25μg**	not determinable	not detern

[a]Data are mean ± SD values of three independent experiments and different letters indicate a significant difference according to an variance and Tukey's *post hoc* test ($p \leq 0.05$) for each mineral evaluated. nd: not detected. This table presents *Dietary Reference Intak* in italics and **Dietary Recommendations** in bold type, both for adult individuals (31-50 years old).

tionship among all fruit constituents and between them and other elements that are present in the diet should be better studied.

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RESUMO

se ampliado nos últimos anos, não só na preparação cos, mas também como matéria-prima para iogurtes biscoitos, bolos, sorvetes e alimentos infantis. No até o momento não há dados sobre o perfil mineral d congeladas. Este trabalho é o primeiro banco de dad quantificar os níveis de minerais em 23 amostras de fru geladas, bastante consumidas em todo o mundo e de a frutas nativas da floresta amazônica, Brasil. Consider as Referências de Ingestão Diárias, 100g de frutas con podem fornecer 0,2-2,8% de macro e de 2,5 a 100% crominerais para adultos (31-50 anos). Embora as dif geográficas devam ser consideradas, estes dados ajud o plano de dietas e desenvolvimento de intervenções

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