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Analysis of Minerals in Foods: A Three-year Survey from Costa Rican Market Products

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Abstract

Developing and carrying out analyzes that allow nutritional profiling of foods has become increasingly necessary in the food industry, especially when essential nutrients, such as minerals, are involved. In addition, having this type of information makes it possible to characterize the food, corroborate labeling, monitor regulations, improve food quality, and take public health measures when there are deficiencies or excesses in the population level of any nutrient. During this survey, total ash, Cl, Ca, P, Mg, Fe, Zn, Cu, Na, and K, were analyzed in different foods (including meat, dairy, cocoa, baked products, fruits, vegetables, legumes, beverages, cocoa products), for a total of n = 2046, 190, 385, 101, 113, 718, 190, 79, 945, and 190 samples, respectively. These samples were compiled from January 2019 to December 2021 as part of routine surveillance of the food industry. Food mineral fraction was assessed by gravimetry, chloride by potentiometry, and the rest of the analytes by spectrometry. Descriptive statistics were produced to analyze the database, and the information was divided by type of food and minerals.

Keywords: food analysis, food nutrition and quality, macro and micronutrients, ash and mineral content, guaranteed label

1. Introduction

Nutritional value is vital as it is the first stage toward characterizing novel or staple food sources; it can be of interest in the food industry for product development, quality control, or regulatory purposes (Thangaraj, 2016). In this regard, ash content, as part of the proximate analysis (Cortés-Herrera et al., 2021), represents the total mineral content in foods. In turn, the mineral composition is an essential characteristic of foods, both from nutritional and food safety standpoints (Soni et al., 2010).

Ash is the inorganic residue after the water, and organic matter have been removed by heating in the presence of oxidizing agents (Md Noh et al., 2020). Ash content determination is necessary for several reasons. i. It is a part of proximate analysis for nutritional evaluation ii. Furthermore, ashing may be considered a sample pretreatment step for analyzing specific minerals. Ash contents of fresh foods are usually bellow five g/100 g (Harris and Marshall, 2017; Okello et al., 2018). Nevertheless, some processed foods such as processed meats can have ash contents as high as 12 g/100 g, e.g., cooked fish tissue (Pushparajan et al., 2012).

On the other hand, essential elements (e.g., Ca, Mg, Fe, Zn, Cu, or K) are required for a balanced diet. Deficiencies should be avoided as they could lead to minor disorders but can also block some of the main activities of the body and be the reason for severe diseases (Cannas et al., 2020), as well as the cause of death of patients with extreme deficiencies. In the case of essential elements such as Fe, Zn, and Cu, their presence in foods at a high concentration level and their excess ingestion may produce toxic effects (Fraga, 2005).

After that, an optimum concentration level for all those elements is responsible primarily for maintaining numerous metabolic functions in mammals (Prashanth et al., 2015). Hence, one could argue that balanced consumption of minerals from foodstuffs, particularly essential elements, is paramount from the quantitative perspective and that the essentiality or toxicity of a particular component of food items is closely related to its concentration.

Intuitively, essential mineral deficiencies can occur when mineral consumption is underestimated. Nevertheless, if consumed over the required level, toxicity effects can be found, and thus strict analytical control of our daily intake of minerals is needed. Therefore, there is a need to control the presence of mineral elements in foods methodically. In this regard, several international organizations have provided nutritional guidelines that include daily intake values of mineral elements (Council for Responsible Nutrition, 2014; EFSA, 2021; NIH, 2020; World Health Organization, 2005).

As dietary reference values for essential trace elements are designed to meet requirements with minimal risk of deficiency and toxicity, risk-benefit analyses have been performed for some minerals, especially those with narrow margins of recommended consumption (Fairweather-Trait et al., 2010). Then their levels in food, especially those items of more common consumption, must be constantly monitored. Additionally, some research has been put forward that discusses the safety margins of mineral addition in foods (Flynn et al., 2017; Kloosterman et al., 2007; Rasmussen et al., 2006) as standards for food biofortification (Blair, 2013).

From an analytical standpoint, techniques that provide information about the total mineral content are based on the fact that they are distinguishable from other matrix components. For example, most minerals are not lost during heating and have low volatility compared to other food components. Three main types of analytical procedures are used to determine the ash content of foods; dry ashing is the most commonly used process (Md Noh et al., 2020). The method chosen for a particular analysis depends on the reason for the study, the type of food analyzed, and the available equipment.

In the specific case of minerals, atomic and ionic spectrometry methods are the most suitable for obtaining their profile in foods (Md Noh et al., 2020). These multi-elemental techniques are the most powerful tools for accurately determining mineral elements in nutrition at the low range of milligrams. Additionally, anions are usually quantified using various techniques including colorimetry, amperometry, and potentiometry/ion-specific electrode measurements, such is the case of Cl^- (EFSA, 2019).

Finally, in terms of guaranteed labeling for food, for example, according to the US FDA, about n = 14 inorganic ions may be listed on the Nutrition Facts label as minerals (i.e., calcium, chloride, chromium, copper, iodine, iron, magnesium, manganese, molybdenum, phosphorus, potassium, selenium, sodium, and zinc) (Dumoitier et al., 2019, US FDA, 2022).

Herein we describe each food type or group assessed during three years, i. a macro nutrient indicator related to mineral content such as dry ash content and ii. the determination of specific mineral content for those analytes considered relevant for label guarantee and nutritionally. This data can serve several interests as it can feed Food Composition Databases (FCDBs, Md Noh et al., 2020), which must be constantly updated with the introduction of new food products to avoid wrong decisions or interpretations. Additionally, FCDBs must be constructed with high-quality, reliable, up-to-date food composition databases and representative of the food consumed by the population.

2. Method

2.1 Reagents

Nitric acid (ACS reagent 70 mL/100 mL, catalog number 438073), silver nitrate (ReagentPlus®, ≥ 99.9 g/100 g, for titration, catalog number S6506), cesium chloride (ReagentPlus®, 99.9 g/100 g, catalog number 289329), lanthanum oxide III (suitable for AAS, ≥ 99.9 g/100 g), sand (standard, washed and dried, catalog number SX0075), aluminum sulfate (99.99 g/100 g, trace metals basis, catalog number 202614), polyvinyl alcohol (molecular weight 89 000 - 98 000, ≥ 99 g/100 g hydrolyzed, catalog number 341584), sodium molybdate dehydrate (ACS reagent, ≥ 99 g/100 g, catalog number 331058), L-ascorbic acid (99 g/100 g, catalog number A929002), and sodium hydroxide (reagent grade, ≥ 98 g/100 g, catalog number S5881) were acquired from Sigma-Aldrich (St. Louis, MO, USA). Mineral standard solutions for Ca (catalog number 119778), Mg (catalog number 119788), Fe (catalog number 119781), Zn (catalog number 119806), Cu (catalog number 119786), Na (catalog number 170238), and K (catalog number 170230) were purchased from Supelco® (Bellefonte, PA, USA) all nitrate salts, traceable to SRM from NIST in HNO_3 0.5 mol L^{-1}, 1 000 mg L^{-1} Certipur®. Phosphorus standard solution [CRM, traceable to NIST, 75.0 mg L^{-1} PO_4^{3-} in H_2O (total), Supelco®]. Ultrapure water (type I, 0.055 µS cm^{-1} at 25 °C, 5 µg L^{-1} TOC) was obtained using an A10 Milli-Q Advantage system and an Elix 35 system (EMD Millipore Burlington, MA, USA).

2.2 Ash Determination

All ash determinations were performed using a muffle furnace (model BF518994C-1, Lindeberg/Blue M, Thermo Scientific, Waltham, MA, USA) and based on AOAC OMA^{SM} methods 920.117, 920.153, 920.93, 923.03, 925.11, 925.51, 930.229, 930.30, 935.39B, 940.26, and 950.14. All ISO 17025 accredited (Cortés-Herrera et al, 2021).

2.3 Chloride Determination

Total chloride content was determined potentiometrically using an automated titrator (862 titrosampler, Metrohm, Herisau, Switzerland) Coupled with an Ag electrode with Ag_2S coating (catalog 6.0430.100S, Titrode, Metrohm). Method was based on AOAC OMA^{SM} methods 937.07, 937.09, 935.47, 941.18, 960.29, 971.27, 976.18, and 2016.03.

2.3.1 Seasonings, Soups, Sauces

From 10.0 to 25.0 g, samples were dissolved in ca. 500 mL of preheated water at 80 ℃. After cooling, the solution was made up to 1 liter and mixed. After adding 2 mL of a 2 mol L^{-1} nitric acid and 5 mL protective colloid (a 40 g/100 mL polyvinyl alcohol solution), the resulting mixture was titrated with $AgNO_3$ solution at 0.1 mol L^{-1} after the first endpoint.

2.3.2 Dairy Products

Approximately two grams or 20 mL of the dairy product was weighed and treated with 7 mL of a 2 mol L^{-1} NaOH solution and mixed with 20 mL of a 20 g/100 mL solution of aluminum sulfate and 50 mL preheated water. The mixture was allowed to settle and then filtered through an ashless filter paper (Whatman 541).

2.3.3 Meat Products

The tissue was cut into small pieces (portions less than 1 cm edge) and homogenized using a knife mill (GRINDOMIX, GM200, Retsch, Hann, Germany). After that, 10 g of ground meat and 140 g of water were mixed until a homogeneous paste was achieved. Finally, 50 g of the previous mixture was transferred into a glass beaker with 50 mL water and 2 mL of a 2 mol L^{-1} HNO_3 solution.

2.4 Mineral Determinations

2.4.1 Atomic Absorption with Flame Ionization

An atomic absorption spectrometer (200 Series, 280 FS AA, Agilent Technologies, Santa Clara, CA, USA) was used to assess mineral content. Coded single-element hollow cathode lamps were provided for each mineral (acquired from Agilent Technologies Ca (catalog number 5610101000), Mg (catalog number 5610103200), Fe (catalog number 5610102700), Zn (catalog number 5610106800), Cu (catalog number 5610101400), and Na (catalog number 5610105300), and K (catalog number 5610104200). Specific analysis conditions are summarized in Table 1.

Table 1. Atomic absorption analysis conditions

Parameter/Element	Ca	Na	Mg	K	Zn	Cu	Fe
Wavelength, nm	422.7	589.0	285.2	766.5	213.9	324.8	248.3
Combustible gas used	Air/Acetylene						
Bandpass, nm	0.5	0.5	0.5	1.0	1.0	1.0	0.2
Fuel flow, L min^{-1}	2						
Mode	Absorption						
$^2H/D_2$ correction	Yes	No	Yes	No	Yes	Yes	Yes
Current, mA	10	5	4	5	5	4	5

Sample treatment was based on dissolving dry residue from ash determination (section 2.2). Specifical treatment conditions for each food group are based on AOAC OMA^{SM} methods 967.08, 970.12, 970.19, 985.35, 987.03, 991.25, and 999.11. In general, to dry ash contained in a 50 mL porcelain crucible, 10 mL HCl 6 mol L^{-1} were added add heated to 80 ℃ for 10 min using a plate. Afterward, the resulting mixture was filtered by gravity using ashless filter paper (ashless Whatman 541, 150 mm, GE Healthcare, Little Chalfont, Buckinghamshire, United Kingdom), and the filtrate was qualitatively recovered in a 100 mL flask. In the case of Na and K and Ca analyses, CsCl (as ion suppressor) and La_2O_3 (to reduce interferences produced by phosphates) are added, reaching final concentrations of 0.5 and 0.1 g/100 mL, respectively. In the case of non-pulp beverages, the analysis is performed directly after sonication (for degassing) and an appropriate dilution.

2.4.2 Spectrophotometry

Total phosphorus determination was performed using the AOAC OMA^{SM} method 995.11. Briefly, the oxidized dry-ashed residue is dissolved as previously described for mineral analysis. Therefore, 1.0-10.0 mL of the resulting solution is neutralized and transferred into a 50 mL volumetric flask and then diluted with 15 mL H_2O.

After that, 20 mL of a molybdate–ascorbic acid solution (52 and 28 mmol L^{-1}, respectively) was added to the test and standard solutions. The resulting blue complex [i.e., $(MoO_2 \cdot 4MoO_3)2 \cdot H_3PO_4$] was measured spectrophotometrically at 823 ± 1 nm (PharmaSpec, UV-1700, Shimadzu Corporation, Kioto Prefecture, Japan).

2.5 Reference Materials

For all assays, each time an analysis batch was performed, reference material was run in parallel to assess method accuracy (see below). FAPAS® (Fera Science, Sand Hutton, York, United Kingdom) quality control materials T2474QC, T01119QC, T2476QC, T2477QC, T25164QC, TET036RM, T2472QC, and T2475QC, were used for ash. Similarly, FAPAS® T0119QC, T20157QC, and T25179QC were used during Cl^- analysis. In the case of minerals, both FAPAS® T1895QC and NIST SRM® 1849a were used for quality control.

2.6 Samples and Statistical Analysis

For all analytes, descriptive statistics were used to organize the data by type of food. All foods subjected to analysis from January 2019 to December 2021 were included in the survey. All study objects were randomly from routine monitoring performed by diverse food manufacturers and producers from the country (Figure 1).

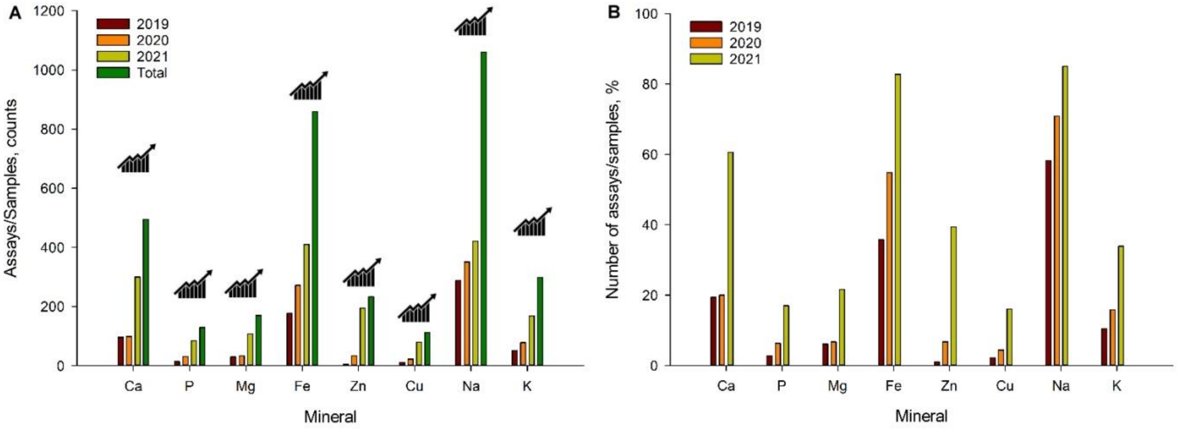

Figure 1. A. Cumulative and individual analysis performed per analyte per year B. number of assays expressed as the percentage of the total analysis

Several categories were constructed based on typical food grouping due to intrinsic characteristics. For each analyte, a seven-point calibration curve was performed for mineral analysis. The final concentrations of the metal were as follows: Ca from 0.6 to 6.0; Na, K, Cu, and Zn from 0.15 to 1.5; Mg from 0.075 to 0.75, and Fe from 0.3 to 3.0 mg L^{-1}. In the case of alcoholic beverages, the calibration curves were matrix-matched accordingly using ethanol. Coefficients of determination ($r^2 \geq 0.98$) and regression equations for each calibration curve prepared during this study were obtained using Sigmaplot 14.5 software (Systat Software Inc., San Jose, CA, USA). Standard deviation certified by the manufacturer or calculated z values were used as method performance parameters. Acceptable z values (i.e., from − 2 to 2) were considered proof of the method's proper bias, accuracy, and recovery during reproducibility conditions. In this scenario, z values indicate the number of standard deviations from the mean of a data point. Mathematically, $z = (x - \mu)/\sigma$. Then, z values are calculated as follows: robust mean concentration (obtained from the method/analyte performance agreed among several laboratories) subtracted by the result from the laboratory divided by the robust standard deviation. Additional paired t-tests and ANOVA were used to assess differences in mineral concentrations between selected samples (Figure 2). An α = 0.05 was used as a threshold to determine significance. These tests were performed using SPSS® Statistics (version 28.0.0, IBM®, Armonk, New York, USA).

Table 2. Summary results for reference materials used for batch analysis approval

Ash			
	Concentration, g/100 g		
Matrix[a]	Assigned value	Acceptable range	Laboratory experimental mean value ± standard deviation
Biscuit [2]	1.44	1.33-1.55	1.352 ± 0.002
Oat flakes [5]	1.69	1.56-1.81	1.657 ± 0.013
Wheat flour [14]	0.81	0.746-0.880	0.822 ± 0.024
Croutons [16]	3.02	2.82-3.23	2.975 ± 0.089
Canned meat [8]	2.10	1.95-2.25	2.097 ± 0.052
Milk powder [30]	5.62	5.58-5.66	5.612 ± 0.032
Milk powder [18]	6.82	6.59-6.85	6.794 ± 0.052
Meat [2]	2.10	1.95-2.25	2.155 ± 0.055
Biscuit [2]	1.21	1.11-1.30	1.190 ± 0.010
Corn flour [2]	1.197	1.104-1.290	1.200 ± 0.019
Chloride			
Tomato paste [10]	0.68	0.619-0.734	0.701 ± 0.032
Canned meat [7]	0.89	0.799-0.973	0.825 ± 0.056
Cheese [5]	0.289	0.233-0.345	0.264 ± 0.045
Minerals			
	Concentration, g/100 g		
Matrix	Assigned value	Acceptable range	Laboratory experimental mean value ± standard deviation
Calcium			
Milk powder [6]	262.10	317.1-372.10	305.28 ± 8.31
Milk powder [32]	525.30	472.77-567.32	512.08 ± 62.15
Milk powder [5]	1 244.50	1 148-1341	1 219.36 ± 59.12
Infant formula [16]	281.10	253.90-308.3	279.93 ± 21.49
Phosphorus			
Milk powder [11]	399.0	359.10-430.92	391.12 ± 11.88
Infant formula [6]	166.35	148.90-183.80	169.85 ± 7.97
Magnesium			
Milk powder [7]	50.35	44.0-56.7	53.46 ± 3.72
Infant formula [17]	164.8	148.32-177.98	172.41 ± 14.92
Iron			
Milk powder [7]	5.20	4.29-6.09	5.82 ± 0.28
Milk powder [22]	5.01	4.12-5.90	5.51 ± 0.35
Infant formula [22]	175.60	149.26-193.16	184.76 ± 10.88
Copper			
Milk powder [8]	0.413	0.307-0.520	0.46 ± 0.11
Infant formula [14]	1.978	1.58-2.27	2.01 ± 0.65
Zinc			
Milk powder [15]	5.08	4.16-6.00	5.25 ± 0.33
Infant formula [23]	15.10	12.83-16.61	13.92 ± 2.69
Sodium			
Milk powder [8]	187.7	146.70-228.70	190.67 ± 19.28
Milk powder [38]	184.5	165.50-203.50	184.92 ± 41.04
Infant formula [24]	426.5	383.85-460.62	401.99 ± 77.36
Potassium			
Milk powder [6]	498.10	437.10-559.10	503.91 ± 37.92
Milk powder [15]	474.15	431.70-516.60	462.99 ± 34.29
Infant formula [15]	922.00	848.24-968.10	901.29 ± 53.59

[a] Numbers in square brackets embody the number of samples *n*.

3. Results and Discussion

3.1 Ash Content

In general, the average ash content for various food groups is given in Table 3. The ash content of most fresh foods rarely exceeds five g/100 g.

In the case of meat products, maximum ash levels, in decreasing order, are as follows: beef meat cuts > sausage > canned meat (i.e., 7.899, 4.711, and 4.205 g/100 g, Table 3). Mean values for sausage and hot dogs are among the highest for these types of products 3.373 and 3.032 g/100 g, respectively (Table 2). Data for meat products align with earlier reports, including chicken cuts (Hussain et al., 2016) and sausages (Khairy et al., 2021; Kolar, 1992; Perez and Andujar, 1980).

In the case of dairy products, milk powder, some cheeses (specially matured ones), and whey exhibited the highest mean values of this food group (i.e., 4.994, 4.689, and 4.055 g/100 g, Table 3). Some reports have stated that ash values represent 11.2% of the dry weight in the original whey (McDonough et al., 1974). Traditional whey protein concentration techniques can increase such values (i.e., up to 15.4 g/100 g after salting out, Tovar Jiménez et al., 2012).

Fruits and fruit juices typically contain little ash (i.e., from ca. 0.2 up to 0.8 g/100 g). See, for example, a ripe banana or melon (Table 3). Exceptions arise for conventionally or freeze-dried fruits, and the latter has recently been trending as a commodity (Sadler, 2019). Freeze-dried fruits can reach up to ca. 8 g ash/100 g sample (e.g., tomatoes Table 3).

Several soups and sauces have considerable amounts of ash content (outstanding mean values of 14.020 to 61.835 g/100 g, Table 2), which is probably translated into sodium intake, as salt concentrations in these products are usually high (Shahar et al., 2019; Tan et al., 2016).

Interestingly, cocoa/cocoa powder exhibited a considerable ash content (i.e., 5.033 and 4.955 g/100 g, respectively, Table 3). On the other hand, within baked products, croutons and sponge cake have the most ash content (i.e., 2.983 and 3.386 g/100 g, Table 3). Again, croutons are seasoned and salted. Additionally, baked products may contain considerable levels of leavening agents (e.g., sodium or ammonium carbonates). Additional data for baked products can be found in an earlier report (Assis dos Passos et al., 2013). Finally, as expected, beverages and sweeteners have the lowest ash levels among most food groups tested (i.e., << 1 g/100 g, Table 3).

Table 3. Ash content in assorted foods assayed during 2019-2021

Matrix[a]	**Mean ± SD**	**Median**	**Maximum**	**Minimum**
	Concentration, g/100 g			
Meat products, n = 446				
Beef meat cuts [205, 10.02, 45.96]	1.278 ± 0.939	0.982	7.899	0.211
Sausage [92, 4.50, 20.63]	3.373 ± 0.387	3.380	4.711	2.529
Pâté [87, 4.25, 19.51]	1.983 ± 0.185	2.085	2.235	1.605
Tuna pâté [20, 0.98, 4.48]	1.812 ± 0.021	1.819	1.847	1.754
Canned meat [12, 0.59, 2.69]	2.819 ± 0.848	2.186	4.205	2.056
Pork butt [9, 0.44, 2.02]	1.386 ± 0.357	1.119	1.929	1.031
Hot dogs [8, 0.39, 1.79]	3.032 ± 0.198	3.007	3.537	2.792
Chicken breast [3, 0.15, 0.67]	2.409 ± 0.126	2.460	2.531	2.236
Fresh tuna [3]	1.572 ± 0.108	1.619	1.674	1.422
Ham [3]	3.132 ± 0.204	3.011	3.419	2.967
Ground beef [2, 0.10, 0.45]	0.899 ± 0.183	0.899	1.082	0.717
Sardines [2]	2.308 ± 0.127	2.308	2.436	2.181
Beverages and drinks, n = 82				
Tea [35, 1.71, 42.68]	0.047 ± 0.018	0.042	0.088	0.013
Apple juice [21, 1.03, 25.61]	0.246 ± 0.210	0.151	0.780	0.015
Kombucha [10, 0.49, 12.20]	0.057 ± 0.037	0.044	0.146	0.017
Beer [5, 0.24, 6.10]	0.106 ± 0.032	0.111	0.146	0.049
Drink mix [3, 0.15, 3.66]	0.234 ± 0.134	0.271	0.376	0.055
Drink mix with probiotics [3]	0.290 ± 0.007	0.294	0.295	0.280
Guava juice [3]	0.294 ± 0.306	0.164	0.828	0.017
Instant tea mix [2, 0.10, 2.44]	1.072 ± 0.074	1.072	1.146	0.998
Dairy products, n = 269				
Milk powder [112, 5.47, 41.64]	4.994 ± 1.992	5.658	7.946	2.126
Evaporated milk [64, 3.13, 23.79]	0.603 ± 0.184	0.552	1.411	0.478
Assorted cheese [40, 1.96, 14.87]	4.055 ± 2.461	3.198	14.102	1.247
Yogurt [28, 1.37, 10.41]	0.867 ± 0.168	0.809	1.334	0.694
Whey [13, 0.64, 4.83]	4.689 ± 3.374	6.930	8.782	0.434
Cow milk [10, 0.49, 3.72]	0.638 ± 0.231	0.725	0.828	0.174
Ice cream mix [2, 0.10, 0.74]	1.301 ± 0.607	1.301	1.908	0.693
Cocoa products, n =33				
Cocoa liquor [13, 0.64, 39.39]	2.224 ± 0.395	2.291	2.883	1.538
Cocoa [6, 0.29, 18.18]	5.033 ± 1.073	5.118	6.793	3.679
Chocolate [6]	2.181 ± 0.395	2.140	2.738	1.707
Cacao nibs [4, 0.20, 12.12]	2.905 ± 0.019	2.917	2.919	2.879
Cacao paste [2, 0.10, 6.06]	3.301 ± 0.015	3.301	3.316	3.286
Cocoa powder [2]	4.955 ± 0.026	4.955	4.981	4.928
Fruits, n = 75				
Dried tomato [20, 0.98, 26.67]	8.123 ± 0.919	8.206	10.149	6.500
Unripe banana [10, 0.49, 13.33]	1.245 ± 0.304	1.249	1.615	0.748

Tacaco (*Sechium tacaco* (Pittier) C. Jeffrey) [6, 0.29, 8.00]	5.131 ±1.262	5.140	6.411	3.826
Melon (*C. melo* L.) [5, 0.24, 6.67]	0.553 ±0.066	0.517	0.673	0.499
Fresh ripe banana [4, 0.20, 5.33]	0.842 ±0.026	0.854	0.863	0.798
Bell peppers [4]	4.794 ±1.943	5.118	7.010	1.929
Apple [3, 0.15, 4.00]	3.248 ±0.034	3.233	3.294	3.215
Cashew (*A. occidentale* L.) [3]	2.148 ±0.037	2.165	2.182	2.097
Costa Rican guava (*P. friedrichsthalianum* (O. Berg) Nied.) [3]	3.252 ±0.117	3.327	3.342	3.086
Jocote (*Spondias purpurea* L.) [3]	2.248 ±0.182	2.366	2.387	1.992
Passion fruit (*P. edulis* Sims) [3]	3.688 ±0.031	3.672	3.731	3.661
Strawberry guava (*P. cattleyanum* Sabine) [3]	3.934 ±0.143	4.010	4.058	3.734
Sweet granadilla/grenadia (*P. ligularis* Juss) [3]	6.089 ±0.398	6.097	6.572	5.597
Sweet lemon (*C. limetta* Risso) [3]	3.671 ±0.063	3.675	3.746	3.593
Dehydrated pineapple [2, 0.10, 2.67]	1.695 ±0.064	1.695	1.758	1.631
Baked products and cereals, n = 45				
Cookies [25, 1.22, 55.56]	1.644 ±0.688	1.508	3.351	0.723
Crouton [7, 0.34, 15.56]	2.983 ±0.033	2.944	3.016	2.899
Breakfast cereal [6, 0.29, 13.33]	0.830 ±0.058	0.859	0.867	0.703
Sponge cake [5, 0.24, 11.11]	3.386 ±0.596	3.120	4.515	2.995
Biscuit [2, 0.10, 4.44]	1.352 ±0.001	1.352	1.354	1.351
Coffee products, n = 405				
Pure roasted coffee [385, 18.82, 95.06]	4.396 ±0.682	4.583	5.946	0.363
Sugar-enriched “Torrefacto” coffee [20, 0.98, 4.94]	3.564 ±0.053	3.551	3.687	3.479
Sweeteners and desserts, n = 54				
Honey [30, 1.47, 55.56]	0.198 ±0.213	0.086	0.851	0.075
Ice cream [9, 0.29, 11.11]	0.860 ±0.256	0.917	1.157	0.313
Corn syrup [6, 0.29, 11.11]	0.309 ±0.081	0.335	0.408	0.194
Caramel [4, 0.20, 7.41]	1.604 ±0.153	1.650	1.745	1.369
Jell-O/Gelatin dessert [3, 0.15, 5.56]	0.406 ±0.445	0.162	1.030	0.025
Refined sugar [2, 0.10, 3.70]	0.022 ±0.008	0.022	0.030	0.014
Grains and cereals, n = 387				
Corn flour [247, 12.07, 63.82]	0.918 ±0.401	0.637	1.587	0.573
Wheat flour [68, 3.32, 17.57]	0.918 ±0.401	0.637	1.587	0.573
Red/Black beans [45, 2.20, 11.63]	2.187 ±0.945	1.228	3.853	0.942
Purple corn [7, 0.34, 1.81]	1.471 ±0.084	1.480	1.582	1.329
Wheat grits [7]	0.880 ±0.051	0.884	0.946	0.783
Oats [5, 0.24, 1.29]	1.661 ±0.008	1.657	1.676	1.655
Corn [3, 0.15, 0.78]	1.287 ±0.092	1.334	1.368	1.159
Canned sweet corn [3]	0.529 ±0.026	0.524	0.563	0.500
White rice [2, 0.10, 0.52]	0.857 ±0.374	0.857	1.231	0.483
Starchy foods, n = 87				
Bread [50, 2.44, 57.47]	2.190 ±0.661	2.227	3.552	0.704
Potato [15, 0.73, 17.24]	3.628 ±0.769	3.734	4.219	0.901
Pasta [19, 0.93, 21.84]	0.891 ±0.227	0.864	1.531	0.463
Tortilla [3, 0.15, 3.45]	1.639 ±0.900	1.315	2.867	0.735
Condiments, Herbs, Spices & Seasonings, n = 54				
Mayonnaise [22, 1.08, 40.74]	1.984 ±0.437	2.133	2.748	1.106
Vanilla [6, 0.29, 11.11]	3.783 ±0.479	3.931	4.359	2.815
Salad dressing [4, 0.20, 7.41]	1.853 ±0.320	1.691	2.404	1.627
Seasoning [4]	8.423 ±3.792	8.529	13.558	3.077
Black peppercorn [3, 0.15, 5.56]	2.315 ±0.691	2.801	2.808	1.338
Chicken soup [3]	61.835 ±4.987	59.819	68.696	56.989
Ginger (*Z. officinale* Roscoe) [3]	1.044 ±0.034	1.051	1.082	1.000
Hot pepper sauce [3]	16.719 ±0.306	16.635	17.128	16.394
Ketchup [3]	3.559 ±0.950	4.219	4.242	2.216
Noodle soup [3]	14.020 ±0.641	14.018	14.807	13.236
	Misc, n = 66			
Edible seaweed powder (dietary supplement) [8, 0.39, 12.12]	7.153 ±2.110	6.387	11.992	4.484
Vitamin supplement [6, 0.29, 9.09]	0.326 ±0.070	0.345	0.404	0.180
Canned mushrooms [5, 0.24, 7.58]	0.952 ±0.197	0.926	1.205	0.674
Kelp [5]	0.839 ±0.200	0.901	1.047	0.569
Vegetable oil [5]	0.035 ±0.030	0.031	0.085	0.002
Banana chips [4, 0.20, 6.06]	2.020 ±0.111	1.992	2.185	1.911
Granola [3, 0.15, 4.55]	2.055 ±0.398	2.069	2.535	1.560
Grape wine [3]	0.201 ±0.007	0.203	0.208	0.192
Marmalade [3]	0.757 ±0.543	0.376	1.524	0.370
Pancake mix [3]	3.286 ±0.237	3.286	3.524	3.049

Pickled vegetables [3]	0.590 ± 0.396	0.391	1.143	0.237
Banana flour [2, 0.10, 3.03]	4.005 ± 0.509	0.637	1.587	0.573
Banana peel [2]	8.578 ± 0.006	8.578	8.584	8.572
Burrito [2]	2.438 ± 0.051	2.438	2.489	2.388
Green beans [2]	2.443 ± 0.072	2.443	2.515	2.371
Lecithin [2]	5.608 ± 1.498	5.608	7.106	4.110
Onion [2]	2.519 ± 0.342	2.519	2.861	2.177
Starch [2]	0.093 ± 0.005	0.093	0.098	0.088
Refried beans [2]	2.022 ± 0.010	2.022	2.032	2.013
Taco [2]	3.170 ± 0.055	3.170	3.224	3.115
Foods with only one hit, n = 43				
	Concentration, g/100 g			
Black garlic [1, 0.05, 2.32]	5.007			
Buffalo milk	0.726			
Cannelloni	0.856			
Carao extract (*C. grandis* L.f.)	0.684			
Carrot cake	1.669			
Cassava flour	2.194			
Coconut caramel	1.450			
Coffee drink	0.320			
Coffee mucilage	0.665			
Confection	1.991			
Corn cake	2.857			
Dry coconut				
Egg	0.878			
Dried seaweed	5.895			
Fresh shrimp	0.594			
Fried plantain	1.027			
Golden berry (*Physalis peruviana* L.)	3.191			
Golden milk	8.101			
Guava (*P. guajava* L.)	0.596			
Hearts of palm	0.887			
Heart of palm paste	0.985			
Jam	0.441			
Kola syrup	1.438			
Lasagna	0.795			
Malanga (*C. esuclenta* (L.) Schott)	1.273			
Malt extract	0.675			
Marshmallow	1.598			
Meat balls	2.146			
Nuggets	2.649			
Orange juice	0.416			
Pignut/chan seeds (*M. suaveolens* (L.) Poit.)	4.005			
Pineapple juice	0.503			
Pitahaya (*H. costaricensis* (F.A.C. Weber) Britton & Rose)	5.473			
Popcorn	0.718			
Sacha inchi (*Plukenetia volubilis* L.)	2.450			
Soursop (*A. muricata* L.)	0.448			
Soursop wine	0.176			
Soymilk	3.078			
Spanish sausage	3.752			
Strawberry	0.386			
Sugar cone	1.026			
Sugarbeet wine	0.080			
Yeast	4.724			

[a] Numbers in square brackets embody in respective order: the number of samples *n*, percentage represented from the total of samples (i.e., *n* = 2043), and percentage represented within each food category.

3.2 Chloride Content

In the case of chloride, in descending order of concentrations, we found assorted seasonings > dressings or pickles >> ketchup > shrimp paste (i.e., mean values of 35.920, 19.562, 3.277, and 3.052 g/100 g, respectively, Table 3). Again, these concentrations can be translated to salt content and intake. In a fascinating result, canned tuna fish in water exhibited significantly more ($p < 0.05$, Table 3) salt than its oil-based counterpart; salt is probably adjusted during processing. Finally, table salt's mean value of 98.848 is closely related to the product's quality control assurance/purity (Table 4).

The number of assays requested historically for Cl^- is less than those for other minerals (Table 4). Probably due to nutritional labeling guidelines focuses/requiring to declare sodium content and daily-recommended values rather than chloride or even salt (Dumoiter et al., 2019; Nieto et al., 2019). However, Capuano and coworkers (2013) already established that a more sound strategy is to determine both chloride and sodium to assess salt (sodium chloride) content, as they may originate from different sources. Interestingly, the authors' salt content using a chloride approach is underestimated (Capuano et al., 2013). In terms of proper analysis, conductimetry/potentiometry has been used as a practical approach to assay chloride content in foods; this is especially true for the cheese industry (see, for example, Aguirre-Londoño et al., 2019). Finally, some studies have found a close relationship between Na^+ and Cl^- balances in the body (EFSA, 2019). Also, NaCl has been described as the main source of both electrolytes in some diets and similar urinary excretion molar levels of these electrolytes are typically observed in some populations (EFSA, 2019).

Table 4. Chloride content in assorted foods assayed during 2019-2021

Matrix[a]	**Mean ± SD**	**Median**	**Maximum**	**Minimum**	**% Daily Value**[b]
	Concentration, g/100 g				*%*
Ketchup [41, 21.58]	3.277 ± 3.850	2.198	16.411	1.630	142
Assorted seasonings [40, 21.05]	35.920 ± 14.629	36.852	77.346	8.961	1561
Whey [28, 14.74]	2.220 ± 1.487	0.950	4.004	0.891	96
Dressing/Pickle [21, 11.05]	19.562 ± 0.408	19.508	20.745	19.023	850
Salt [11, 5.79]	98.848 ± 1.021	99.242	99.491	96.434	4297
Canned tuna in oil [6, 3.16]	0.752 ± 0.213	0.723	1.169	0.496	33
Canned tuna in water [6]	0.971 ± 0.496	0.866	1.816	0.397	42
Mayonnaise [6]	1.672 ± 0.024	1.672	1.696	1.648	73
Beef meat cuts [5, 2.63]	1.483 ± 0.175	1.502	1.650	1.165	64
Grounded/Minced beef meat [5]	1.335 ± 0.033	1.324	1.401	1.305	58
Chocolate mixture [4, 2.11]	0.220 ± 0.008	0.220	0.0228	0.212	10
Vanilla mixture [4]	0.186 ± 0.030	0.180	0.231	0.153	8
Sausage [3, 1.58]	1.593 ± 0.019	1.593	1.612	1.574	69
Tartar sauce [3]	1.744 ± 0.034	1.729	1.791	1.711	76
White wine [3]	0.025 ± 0.003	0.025	0.028	0.022	1
Canned Peas/Peas and carrots [2, 1.05]	1.593 ± 0.019	1.593	1.612	1.574	69
Shrimp pâté [2]	3.052 ± 0.061	3.052	3.113	2.992	132
Foods with only one hit					
	Concentration, g/100 g				*%*
Canned chickpeas	1.128				49
Heat of palm	0.643				28

[a] Numbers in square brackets embody in respective order: the number of samples *n* and percentage represented from the total samples (i.e., *n* = 190). [b] Daily values according to US FDA, 2022 (i.e., 2 300 mg for chloride); mineral input calculated per 100 g food matrix.

3.3 Mineral Analysis

Calcium, phosphorus, and magnesium

Calcium content

Overall, foods have a considerable amount of Ca compared with other minerals studied. Food with significant Ca includes orange, tomato, and sweet lemon. In the specific case of tomato, mean levels of 180.42 mg/100 g were obtained (Table 5, Figure 2A), whereas, in comparison, ca. 7.08 mg/100 g has been reported near the Mediterranean Sea for this fruit (Rosa-Martínes et al., 2021); a reasonably high gap.

On the other hand, dairy products (cheese, yogurt, milk, and ice cream) have a significant concentration of Ca (i.e., from 131.039 to 708.366 mg/100 g, respectively, Table 4). These present important concentrations of Ca compared to the rest of the foods. In comparison, Ca concentrations in milk from Northern Italy were 14.718 mg/100 g. In other European countries, higher mean values such as 147.710 mg/100 g have been reported. Such relatively low levels in milk are usually subject to compensation by enrichment (Vigolo et al., 2022). It is worth mentioning that meat has a concentration of Ca ranging from 117.22 to 699.59 mg/100 g (Table 4), one of the foods with a broader range of Ca concentration (Table 5, Figure 2A).

Such elevated levels are attained in tissue, and dairy is related to animal nutrition and supplementation provided to the animal. Additionally, it is associated with the type of proteins present in these products (Stergiadis et al., 2019).

In the case of coffee, values of Ca in ground roasted coffee are generally low. In fact, several fortification strategies exist (de Paula et al., 2014). However, values as high as 1 080 mg/100 g in coffee silverskin have been reported (Nzekoue et al., 2022). Costa Rica is one of Latin America's largest coffee producers and consumers. It is said that the consumption of coffee per day (8 ounces) is equivalent to consuming 400 mg of caffeine per day (Reyes and Cornelis, 2018). Hence, it is vital to know the quality of this product. On a related note, reported values for tea are close to the maximum value reported elsewhere (Liu et al., 2022). In Costa Rica, tea consumption competes mainly with coffee (Kings and Cornelis, 2018).

Finally, studies have shown that the consumption of Ca in Costa Rica is around 570.3 mg, one of the most consumed minerals, second only to K with 2 172.1 mg (Monge-Rojas et al., 2021).

Table 5. Foods for which calcium analyses were surveyed from 2019 to 2021

Matrix[a]	**Mean ± SD**	**Median**	**Maximum**	**Minimum**	**Daily Value**[b]
	Concentration, mg/100 g				*%*
Dairy and dairy products, n = 203					
Milk [96, 24.94, 47.29]	85.46 ± 43.83	75.16	192.84	25.68	6
Milk Powder [75, 19.48, 36.95]	708.37 ± 299.25	820.27	1264.8	3.53	54
Cheese [16, 4.16, 7.88]	629.48 ± 224.06	681.45	980.69	59.04	48
Yogurt [8, 2.08, 3.94]	131.04 ± 15.84	131.12	156.24	110.83	10
Cheese whey [5, 1.30, 2.46]	61.59 ± 47.45	41.39	152.36	15.02	4
Ice Cream [3, 0.78, 1.48]	155.42 ± 73.39	182.39	228.73	55.15	12
Misc, n = 104					
Cocoa (*Theobroma cacao* L.) [26, 6.75, 25.00]	141.69 ± 166.08	68.94	545.22	10.82	11
Meat [13, 3.38, 12.50]	350.27 ± 178.00	310.12	699.59	117.21	27
Powdered drinks [11, 2.86, 10.58]	8.95 ± 7.16	5.92	23.15	0.02	0.7
Edible seaweed (*Chlorophyta*) [9, 2.34, 8.65]	257.06 ± 264.98	139.33	893.88	29.93	20
Cookies [7, 1.82, 6.73]	110.81 ± 115.22	44.37	378.48	28.86	8
Corn meal [6, 1.56, 5.77]	16.16 ± 3.25	14.63	21.90	12.98	1
Corn [6]	4.03 ± 3.65	5.94	8.91	3.71	0.3
Ham [4, 1.04, 3.85]	15.88 ± 9.29	12.96	31.25	6.34	1
Breakfast cereal [3, 0.78, 2.88]	4.45 ± 0.39	4.29	4.99	4.07	0.3
Bean (*Phaseolus vulgaris* L.) [3]	63.54 ± 49.12	29.02	133.00	28.60	5
Cassava fluor [3]	41.54 ± 8.59	44.53	50.25	29.86	3
Honey [3]	24.23 ± 18.88	14.96	50.55	7.19	2
Starch [2, 0.52, 1.92]	2.83 ± 0.22	2.83	3.05	2.62	0.2
Marshmellows [2]	12.51 ± 6.15	12.51	18.66	6.35	1
Pasta [2]	21.47 ± 4.82	21.47	26.29	16.65	1
Chicken [2]	2.76 ± 3.71	2.76	6.47	0.956	0.2
Tea [2]	1.87 ± 0.67	1.87	2.53	1.21	0.1
Fruits, n = 60					
Tomato (*Solanum lycopersicum* L.) [22, 5.71, 36.67]	180.42 ± 60.35	190.70	263.51	14.71	14
Dragon fruit (*Hylocereus costaricensis* (F.A.C. Weber) Britton & Rose) [12, 3.12, 20.00]	9.49 ± 3.67	10.18	14.97	3.82	0.7
Banana (*Musa paradisiaca* L.) [5, 1.30, 8.33]	12.53 ± 8.19	7.47	26.09	3.95	1
Jocote [*Spondias purpurea* L.] [3, 0.78, 5.00]	47.15 ± 2.09	47.02	49.77	44.66	3
Sweet Lemon (*Citrus limetta* Risso) [3]	194.47 ± 20.46	191.24	220.99	171.18	15
Malay (rose) apple (*Syzygium malaccense* (L.) Merr. & L.M. Perry) [3]	77.00 ± 7.40	72.35	87.44	71.20	6
Passion Fruit (*Passiflora edulis* Sims) [3]	21.66 ± 4.39	18.81	27.86	18.31	1
Peach Palm (*Bactris gasipaes* Kunth) [3]	71.36 ± 2.03	71.87	73.54	68.65	5
Cashew (*Anacardium occidentale* L.) [3]	12.62 ± 0.67	12.43	13.51	11.91	1
Tacaco (*Sechium tacaco* (Pittier) C. Jeffrey) [3]	348.23 ± 59.64	370.49	407.55	266.64	27
Foods with only one hit, n = 18					
	Concentration, mg/100 g				*%*
Dressing [1, 0.26, 5.56]	19.32				1
Garlic (*Allium sativum* L.)	43.45				3
Biscuit	110.48				8
Coffee (*Coffea arabica* L.)	6.29				0.5
Onion (*Allium cepa* L.)	20.27				1
Sweet pepper (*Capsicum annuum* L.)	14.30				1
Candy	238.54				18
Caramel	277.86				21
Bread	13.87				1
Mushroom	21.67				1
Whole Egg	56.52				4
Jelly	40.86				3
Soy Milk	364.00				28
Coffee mucilage	24.10				2

Orange (*Citrus sinensis* (L.) Osbeck)	254.28	20
Pepper	258.56	20
Cream Cheese	247.17	19
Tartar Sauce	40.62	3

[a]Numbers in square brackets embody in respective order: the number of samples *n*, percentage represented from the total of samples (i.e., *n* = 190), and percentage represented within each food category. [b]Daily values according to US FDA, 2022 (i.e., 1 300 mg for calcium); mineral input calculated per 100 g food matrix.

Phosphorus content

Phosphorus is an intestinal-absorbed essential micronutrient in human nutrition (Gutiérrez, 2020). In its inorganic and organic forms (Gutiérrez, 2020; Schwerbel et al., 2022), it participates in several metabolic processes (e.g., phosphorylation reactions, intracellular acid-base balance) and is a component of nucleic acids, cellular membranes, and some organelles (Gutiérrez, 2020; Schwerbel et al., 2022), respectively. Daily requirements for the mineral in adults are 1 200 mg day^{-1}, with a Ca:P relationship of 1.7 (Gutiérrez et al., 2020).

Foods with high protein content usually possess high P levels, including milk, eggs, meat products, legumes, and seeds. Nevertheless, vegetable sources of P tend to render it indigestible due to phytic acid; then, P bioavailability is higher in products of animal origin (Schwerbel et al., 2022; St-Jules, 2016 et al., 2016).

In accordance with the above, Table 5 shows that the products with higher P levels are algae (1 194.31 mg/100 g), fruits (e.g., sweet granadilla, tomato, and tacaco with values of 246.71, 417.64, and 370.49 mg/100 g, respectively) followed by milk powder (i.e., 326.40 ± 218.31 mg/100 g) (Table 6, Figure 2B). Despite the nutritional relevance of P, a skewed balance in relation to its Ca counterpart can unleash severe metabolic issues (Gutiérrez et al., 2020; St-Jules et al., 2016; Tuominen et al., 2022).

Currently, in the food industry, P-containing compounds are used to improve flavor and appearance and increase the shelf life of processed foods, among other applications. This has increased phosphorus concentrations in people's diets, as opposed to a decrease in calcium consumption (Gutiérrez et al., 2020; Tuominen et al., 2022).

Table 6. Phosphorus content in assorted foods assayed during 2019-2021

Matrix[a]	**Mean ± SD**	**Median**	**Maximum**	**Minimum**	**Daily Value**[b]
	Concentration, mg/100 g				*%*
Misc, n = 43					
Cocoa and by-products [10, 9.90, 23.26]	139.89 ± 21.56	136.34	180.14	109.96	11
Edible seaweed [8, 7.92, 18.60]	1 194.31 ± 215.92	1 142.76	1 681.11	946.28	95
Milk powder [12, 11.88, 27.91]	326.40 ± 218.31	268.40	960.03	154.67	24
Whey [5, 4.95, 11.63]	31.29 ± 8.31	35.22	37.82	15.12	2
Beverage [3, 2.97, 6.98]	15.02 ± 5.85	13.26	24.41	7.92	1
Honey [3]	13.74 ± 9.22	8.47	26.71	6.04	1
Breakfast cereal [2, 1.98, 4.65]	55.90 ± 3.86	55.90	59.77	52.04	4
Fruits, Vegetables & Others, n = 53					
Tomato [23, 22.77, 43.40]	417.64 ± 116.80	459.76	539.99	130.93	33
Dragon fruit [9, 8.91, 16.98]	24.80 ± 5.02	22.17	33.68	19.78	2
Cashew (*A. occidentale* L.) [3, 2.97, 5.66]	98.15 ± 8,61	102.54	105.79	86.11	8
Sweet granadilla/grenadia (*P. ligularis* Juss) [3]	246.71 ± 9.32	241.30	259.82	238.99	20
Jocote (*Spondias purpurea* L.) [3]	171.56 ± 3.87	170.78	176.64	167.27	14
Passion fruit [3]	231.54 ± 7.19	227.51	241.64	225.46	18
Peach-palm [3]	82.28 ± 3.00	81.09	86.41	79.36	6
Sweet lemon (*C. limetta* Risso) [3]	135.65 ± 2.38	135.19	138.77	133.00	11
Tacaco (*Sechium tacaco* (Pittier) C. Jeffrey) [3]	370.49 ± 4.10	367.89	376.28	367.29	30
Foods with only one hit, n = 5					
	Concentration, mg/100 g				*%*
Corn [1, 0.99, 20.00]	308.84				25
Garlic	472.66				38
Coffee mucilage	19.87				1
Mushroom	692.72				55
Rice	295.93				24

[a]Numbers in square brackets embody in respective order: the number of samples *n*, percentage represented from the total of samples (i.e., *n* = 190), and percentage represented within each food category. [b]Daily values according to US FDA, 2022 (i.e., 1 250 mg for phosphorus); mineral input calculated per 100 g food matrix.

Magnesium content

Another crucial dietary micronutrient is Mg, the second cation of most abundance within the cell. It is also stored within bones and is an enzymatic co-factor, which means it is involved in a variety of metabolic pathways (e.g., Ca and K active transport through membranes, protein synthesis, and parathyroid hormone secretion (Capozzi et al., 2020; Djinovic-Stojanovic et al., 2017; Jodral-Segado et al., 2003; Pardo et al., 2021).

On the other hand, mineral deficiencies can directly affect bone structure by favoring the increase of osteoclasts over osteoblasts. In contrast, hypomagnesemia is also associated with chronic gastrointestinal diseases and liver and kidney diseases (Capozzi et al., 2020; Pardo et al., 2021).

This mineral is present in a wide variety of foods, mainly green vegetables, dry seeds, and marine products (i.e., with reports as high as 500 mg kg^{-1} fresh weight; Jodral-Segado et al., 2003). Meanwhile, cereals, tubers, fruits, fats, and oils contribute just 100 mg kg^{-1} fresh weight (Djinovic-Stojanovic et al., 2017).

Recommended daily consumption of Mg for women and men is set at 320 and 420 mg, respectively (Capozzi et al., 2020). Additionally, infant formula must be fortified at 54 – 100 mg day^{-1} (Capozzi et al., 2020). Following the above, vegetable sources exhibit higher Mg levels (Table 7, Figure 2C).

Table 7. Magnesium content in assorted foods assayed during 2019-2021

Matrix[a]	**Mean ± SD**	**Median**	**Maximum**	**Minimum**	**Daily Value**[b]
	Concentration, mg/100 g				*%*
Misc, n = 60					
Cocoa and by-products [19, 16.81, 31.67]	265.78 ± 89.29	278.82	455.18	135.17	64
Milk powder [12, 10.62, 20.00]	108.97 ± 58.79	85.98	190.67	44.84	26
Edible seaweed [10, 8.85, 16.67]	317.49 ± 114.08	278.69	582.55	187.52	76
Beverages [8, 7.08, 13.33]	49.92 ± 64.75	13.59	161.65	3.29	12
Whey [5, 4.42, 8.33]	7.48 ± 3.87	8.20	13.21	1.80	2
Breakfast cereal [3, 2.65, 5.00]	15.31 ± 0.21	15.16	15.61	15.16	4
Honey [3]	31.09 ± 39.91	3.46	87.53	2.28	7
Fruits, Vegetables & Others ¸n = 48					
Tomato [20, 17.70, 41.67]	136.3 ± 15.69	142.18	156.54	103.33	32
Dragon fruit [6, 5.31, 12.50]	15.49 ± 6.84	14.55	24.26	7.35	3
Passion fruit [4, 3.54, 8.33]	101.40 ± 18.97	106.08	122.47	70.96	24
Cashew (*A. occidentale* L.) [3, 2.65, 6.25]	44.51 ± 4.33	42.07	50.59	40.87	10
Sweet granadilla/grenadia (*P. ligularis* Juss) [3]	35.37 ± 2.27	34.87	38.37	32.89	8
Jocote (*Spondias purpurea* L.) [3]	62.04 ± 2.02	62.78	64.06	59.29	15
Peach-palm [3]	54.02 ± 0.73	54.02	54.92	53.12	13
Sweet lemon (*C. limetta* Risso) [3]	57.55 ± 5.32	54.06	65.07	53.51	14
Tacaco (*Sechium tacaco* (Pittier) C. Jeffrey) [3]	183.50 ± 32.82	192.36	218.52	139.62	44
Malay (rose) apple [3]	148.41 ± 59.12	108.47	232.00	104.77	35
Foods with only one hit, n = 5					
	Concentration, mg/100 g				*%*
Cassava meal [1, 0.88, 20.00]	36.82				9
Corn	107.04				25
Garlic	100.22				24
Coffee mucilage	9.00				2
Mushroom	186.09				44

[a] Numbers in square brackets embody in respective order: the number of samples *n*, percentage represented from the total of samples (i.e., *n* = 190), and percentage represented within each food category. [b] Daily values according to US FDA, 2022 (i.e., 420 mg for magnesium); mineral input calculated per 100 g food matrix.

Iron, zinc, and copper

Iron content

Compared to the rest of the foods present in this study, Fe is found in high concentrations in pasta, flours, cereals, and multivitamins (Table 7). Foods containing considerable concentrations of Fe are flour (5.57 mg/100 g), cereal (15.44 mg/100 g), and pancake (5.69 mg/100 g), all of which contain wheat or corn (Table 8, Figure 2D). Corn and wheat formulations contain high levels of Fe due to decrees made in Costa Rica for their fortification. The first decree was emitted in 1966, and the fortification levels were doubled in 1996 due to the need to have food with a nutritional status necessary for the population with highly bioavailable Fe species. With the arrival of fortification, surveillance programs were also implemented by corn flour and milk processing plants (Alfaro and Salas, 2006). In Costa Rica, the maximum fortification level of corn flour is 60 mg kg^{-1} (Decree No. 26371-s in 1997; PAHO, 2006).

Additionally, multivitamins stand out with a Fe concentration of 245.96 mg/100 g (Table 8, Figure 2D). In Costa Rica, it is indicated that the minimum amount of Fe dietary supplements should be a minimum of 3.6 mg and a maximum of 60 mg per day (Decree No.-36134-S).

The Fe needed per day is ca. 18 mg daily (US FDA, 2022). Both this mineral and Zn are used chiefly in biofortification processes which increase the mineral value in food and thus, increase its nutritional value. Nevertheless, mineral levels must be supervised not to exceed the necessary amount of Fe per diet of an average person (Pachón et al., 2009).

The biological relevance of Fe lies in the synthesis of the heme group (e.g., synthesis of protoporphyrin, hemoglobin, or reactions such as oxidation-reduction and enzyme peroxidases or catalases). Iron deficiency causes anemia (i.e., liver and bone marrow lack normal Fe reserves). Interestingly, although you can count on higher amounts of Fe in vegetables than in meats, the former reservoirs are less bioavailable (Trumbo et al., 2001).

The beef consumption in Costa Rica at home is approximately 2.2 kg per week. Studies have shown that in Latin America and the Caribbean, there is a consumption of roughly 60 kilograms of meat per year per person, very similar to people in Europe and Oceania. In contrast, North Americans consume 96 kg of meat per person yearly (OECD-FAO, 2019).

Table 8. Foods for which iron analyses were surveyed from 2019 to 2021

Matrix[a]	**Mean ± SD**	**Median**	**Maximum**	**Minimum**	**Daily Value**[b]
	Concentration, mg/100 g				*%*
Cereals, grains, seeds, and derived products, n = 351					
Wheat flour [285, 39.69, 81.20]	5.57 ± 2.12	5.99	9.95	0.93	31
Pasta [19, 2.65, 5.41]	4.17 ± 2.31	5.09	7.58	1.49	23
Wheat semolina [13, 1.81, 3.70]	4.10 ± 0.58	4.08	5.03	2.68	23
Crackers [10, 1.39, 2.85]	5.31 ± 1.85	4.98	8.88	2.73	30
Cornmeal [7, 0.97, 1.99]	2.89 ± 0.82	2.40	4.34	2.28	16
Bean (*Phaseolus vulgaris* L.) [6, 0.84, 1.71]	3.25 ± 1.27	2.67	5.33	2.10	18
Corn (*Zea mays* L.) [6]	3.12 ± 0.73	2.96	4.46	2.27	17
Breakfast Cereal [5, 0.70, 1.42]	15.44 ± 1.80	15.28	18.77	13.47	86
Dairy products, n = 48					
Milk Powder [35, 4.87, 72.92]	8.71 ± 5.79	2.40	4.34	2.28	48
Cheese [9, 1.25, 18.75]	0.36 ± 0.20	0.27	0.81	0.14	2
Yogurt [4, 0.56, 8.33]	0.30 ± 0.19	0.22	0.63	0.14	2
Misc, n = 78					
Multivitamin [22, 3.06, 28.21]	245.96 ± 352.45	70.08	1 086.80	39.26	1 366
Cocoa (*Theobroma* cacao L.) [18, 2.51, 23.08]	2.46 ± 1.49	3.77	12.94	1.24	14
Corn syrup [11, 1.53, 14.10]	50.34 ± 10.70	49.14	69.39	32.01	280
Edible seaweed (Chlorophyta) [7, 0.97, 8.97]	127.93 ± 112.73	81.74	393.00	51.49	711
Flower flour [4, 0.56, 5.13]	7.11 ± 0.77	7.26	7.98	5.96	40
Honey [4]	0.65 ± 0.31	0.53	1.16	0.37	3
Powdered drinks [3, 0.42, 3.85]	0.30 ± 0.08	0.34	0.38	0.19	2
Tea [3]	2.15 ± 2.91	0.10	6.26	0.09	12
Starch [2, 0.28, 2.56]	0.71 ± 0.08	0.71	0.78	0.63	4
Cassava flour [2]	1.33 ± 0.42	1.33	1.76	0.91	7
Pancake [2]	4.33 ± 0.01	4.33	4.35	4.32	24
Meat and meat products, n = 158					
Tuna Paté [88, 12.26, 55.70]	1.11 ± 0.30	1.10	2.54	0.64	6
Paté [61, 8.50, 38.61]	0.95 ± 0.65	0.83	5.55	0.57	5
Ham [4, 0.56, 2.53]	0.80 ± 0.59	0.47	1.83	0.43	4
Meat cuts [3, 0.42, 1.90]	7.09 ± 4.43	9.39	10.98	0.90	40
Chicken [2, 0.28, 1.27]	0.86 ± 0.19	0.86	1.05	0.67	5
Fruits, n = 65					
Tomato (*Solanum lycopersicum* Lam) [22, 3.06, 33.85]	4.76 ± 1.39	17.16	20.75	4.63	26
Dragon fruit (*Hylocereus costaricensis* (F.A.C. Weber) Britton & Rose) [9, 1.25, 13.85]	0.42 ± 0.28	0.30	0.84	0.15	2
Banana [5, 0.70, 7.69]	0.40 ± 0.12	0.47	0.53	0.20	2
Melon (*Cucumis melo* L.) [5]	1.21 ± 0.26	1.11	1.65	0.88	7
Cashew (*Anacardium occidentale* L.) [3, 0.42, 4.62]	1.10 ± 0.13	1.19	1.20	0.92	6
Granadilla (*Passiflora ligularis* Juss) [3]	2.40 ± 0.02	2.39	2.42	2.38	13
Jocote [*Spondias purpurea* L.] [3]	1.56 ± 0.08	1.53	1.67	1.49	8
Malay (rose) apple (*Syzygium malaccense* (L.) Merr. & L.M. Perry)) [3]	1.30 ± 0.06	1.31	1.37	1.21	7
Passion Fruit (*Passiflora edulis* Sims) [3]	3.62 ± 0.42	3.45	4.19	3.21	20

Peach Palm (*Bactris gasipaes* Kunth) [3]	1.12 ±0.11	1.15	1.23	0.97	6
Sweet Lemon (*Citrus limetta* Risso) [3]	1.89 ±0.46	1.58	2.55	1.54	10
Tacaco (*Sechium tacaco* (Pittier) C. Jeffrey) [3]	4.87 ±0.19	5.00	5.01	4.60	27
Foods with only one hit, n = 18					
	Concentration, mg/100 g				*%*
Dressing [1, 0.14, 5.56]	0.970				5
Garlic (*Allium sativum* L.)	2.806				15 589
Rice (*Oryza sativa* L.)	0.957				5
Coffee (*Coffea arabica L.*)	0.334				2
Shrimp	5.382				29 900
Onion (*Allium cepa L.*)	4.089				22 717
Pepper (*Capsicum annuum L.*)	1.091				6 061
Candy	1.087				6 039
Caramel	0.259				1
Bread	1.308				7 267
Whole Egg	1.937				10 761
Jelly	3.796				21 089
Milk	1.357				7 539
Marshmellows	0.831				5
Coffee mucilage	3.991				22 172
Orange (*Citrus sinensis* (L.) Osbeck)	1.810				10 055
Pepper	6.047				33 594
Tartar Sauce	1.122				6 233

[a] Numbers in square brackets embody in respective order: the number of samples *n*, percentage represented from the total of samples (i.e., *n* = 190), and percentage represented within each food category. [b] Daily values according to US FDA, 2022 (i.e., 18 mg for iron); mineral input calculated per 100 g food matrix.

Zinc content

Zn is a significant enzyme co-factor, part of the antioxidant defense of the organism (e.g., Cu-Zn superoxide dismutase), necessary in cellular processes, and participates in the metabolism of carbohydrates, proteins, and lipids (Bloom et al., 2021; Garagarza et al., 2022). The recommended amount of zinc in the diet is 8 and 11 mg day^{-1} for women and men, respectively. Like Mg, it is urgently required in the early stages of life. Therefore, 6 to 11 mg day^{-1} is required (Garagarza et al., 2022). According to table 8, most Zn food-related sources come from vegetables, milk powder (8.62 ±4.81 mg/100 g), and cookies (13.60 ±0.39 mg/100 g). One interesting finding is that prepared beverages, especially iced tea preparations, include Zn sources in their formulation (i.e., mean values 1.00 mg Zn/100 g). Still, also they have been constantly monitored for this mineral level (Table 9, Figure 2E).

On the other hand, the primary sources of zinc are found in marine products, especially oysters, red meat, dairy products, chicken, eggs, and legumes such as beans (Garagarza et al., 2022). However, beans on their own are a highly nutritious food since they have high levels of fiber, vitamins, and minerals, including zinc. However, antinutritional factors such as phytic acid, polyphenols, lectins, and tannins decrease zinc absorption in the body (Huertas et al., 2022). This implies that vegetarian or vegan diets are the most susceptible to Zn deficiencies and the most vulnerable people include populations from countries in Southeast Asia, India, Pakistan, and North America (Kumar et al., 2022; Pratap-Singh and Leiva, 2021).

Dietary Zn deficiency can be associated with anorexia, alopecia, anemia, severe chronic diseases, a weak immune system, and growth retardation (Bloom et al., 2021; Huertas et al., 2022; Garagarza et al., 2022). Hence, multiple governments have relied on the strategy of fortifying and enriching foods, mainly with Fe, I, Zn, and vitamin A) to combat nutritional deficiencies, especially because malnutrition in children under five years of age can cause delays in their physical and mental development (Taghi Gharibzahedi and Mahdi Jafari, 2017). Either complete nutritional foods or nutrients widely consumed by a large part of the population (especially the population at socioeconomic risk) are used as vehicles for micronutrients (e.g., wheat, corn, rice, dairy products, sugar, salt) (Pratap-Singh and Leiva, 2021; Taghi Gharibzahedi and Mahdi Jafari, 2017).

Table 9. Zinc content in assorted foods assayed during 2019-2021

Matrix[a]		**Median**	**Maximum**	**Minimum**	**Daily Value**[b]
	Concentration, mg/100 g				*%*
Misc, n = 136					
Iced tea preparations [76, 40.00, 55.88]	1.00 ±0.13	0.97	1.31	0.76	9
Beverage mix [20, 10.53, 14.71]	1.39 ±0.54	1.54	2.39	0.18	12
Milk powder [15, 7.89, 11.03]	8.62 ±4.81	5.40	15.28	1.69	78

Cocoa and by-products [9, 4.74, 6.62]	3.90 ± 1.06	4.35	5.01	1.72	35
Edible seaweed [7, 3.68, 5.15]	3.73 ± 2.05	2.84	6.54	1.33	34
Honey [3, 1.58, 2.21]	0.30 ± 0.15	0.31	0.48	0.10	3
Biscuit [2, 1.05, 1.47]	13.60 ± 0.39	13.60	14.00	13.21	124
Breakfast cereal [2]	0.43 ± 0.01	0.43	0.44	0.42	4
Rice [2]	1.48 ± 0.07	1.48	1.55	1.41	13
Fruits, Vegetables & Others, n = 49					
Tomato [20, 10.53, 40.82]	3.06 ± 0.81	2.88	5.44	2.24	28
Melon (*C. melo* L.) [5, 2.63, 10.20]	0.23 ± 0.05	0.23	0.30	0.17	2
Cashew (*A. occidentale* L.) [3, 1.58, 6.12]	1.70 ± 0.54	1.36	2.46	1.29	15
Sweet granadilla/grenadia (*P. ligularis* Juss) [3]	2.94 ± 0.16	2.83	3.17	2.82	27
Jocote (*Spondias purpurea* L.) [3]	1.18 ± 0.09	1.16	1.29	1.07	11
Passion fruit [3]	2.96 ± 0.17	2.94	3.17	2.76	27
Peach-palm [3]	0.88 ± 0.16	0.87	1.08	0.69	8
Sweet lemon (*C. limetta* Risso) [3]	1.31 ± 0.40	1.49	1.68	0.75	12
Tacaco (*Sechium tacaco* (Pittier) C. Jeffrey) [3]	3.95 ± 0.08	3.95	4.05	3.85	36
Malay (rose) apple [3]	5.60 ± 3.06	5.12	9.56	2.11	51
Foods with only one hit ¸n = 5					
	Concentration, mg/100 g				*%*
Bean [1, 0.53, 20.00]	0.90				8
Cassava meal	2.16				20
Garlic	3.41				31
Coffee mucilage	0.44				4
Mushroom	0.83				7

[a] Numbers in square brackets embody in respective order: the number of samples *n*, percentage represented from the total of samples (i.e., *n* = 190), and percentage represented within each food category. [b] Daily values according to US FDA, 2022 (i.e., 11 mg for zinc); mineral input calculated per 100 g food matrix.

Copper content

Regarding Cu, cocoa is one of the foods that contain more Cu, with a concentration of 1.65 mg/100 g (Table 10, Figure 2F). The concentration of Cu in cocoa reported in the literature is approximately 0.610 mg/100 g. Differences arise primarily from the presence of this metal in the soil (Vriesmann et al., 2011). Related studies of Costa Rican soil, ranging from 60.0-307.0 mg Cu kg^{-1}, indicate that this mineral is at significantly higher levels than in other countries [i.e., a worldwide average of 13-24 mg kg^{-1} (Rigoberto et al., 2012)]. Additionally, the increased concentration of this metal in food may be related to using fungicides in plantations (Bllabio et al., 2018). Cocoa is economically relevant for the country, as Costa Rica is considered one of the top producers in Latin America (Mustiga et al., 2018).

Please note that tomato contains a concentration of 1.95 mg/100 g of Cu (Table 10, Figure 2F). In contrast, mean concentrations of 0.67 mg/100 g have been reported previously (Ali et al., 2020).

The daily-recommended consumption of Cu is around 0.9 mg, whereas most foods have low concentrations ranging from 0.05 to 1.95 mg/100 g (US FDA, 2022). Cu is one of the essential minerals for the immune system and is an important co-factor for catalytic activity. The deficiency of this mineral can have adverse health consequences. Such as anemia and neutropenia (Vinha et al., 2019). However, excessive amounts of the mineral might also produce adverse health effects such as the production of free radicals that cause lipid peroxidation and interfere with metabolism leading to decreased cortex and bone strength (Vinha et al., 2019). Noteworthy, Zn and Cu directly compete for intestinal absorption (Vinha et al., 2019).

Table 10. Foods for which copper analyses were surveyed from 2019 to 2021

Matrix[a]	**Mean ± SD**	**Median**	**Maximum**	**Minimum**	**Daily Value[b]**
	Concentration, mg/100 g				*%*
Misc, n = 30					
Cocoa (*Theobroma cacao* L.) [9, 11.39, 30.00]	1.65 ± 0.26	1.76	2.03	1.32	183
Milk powder [9]	1.30 ± 0.75	1.69	2.11	0.44	144
Edible seaweed (Chlorophyta) [7, 8.86, 23.33]	1.59 ± 0.65	1.91	2.24	0.59	176
Honey [3, 3.80, 10.00]	0.05 ± 0.07	0.017	0.146	0.02	5
Powdered drinks [2, 2.53, 6.67]	1.04 ± 0.08	1.04	1.12	0.95	115
Fruits, n = 44					
Tomato (*Solanum lycopersicum* Lam) [20, 25.32, 45.45]	1.94 ± 0.42	1.50	3.18	0.42	215
Cashew (*Anacardium occidentale* L.) [3, 3.80, 6.82]	0.81 ± 0.06	0.78	0.89	0.76	90
Jocote [*Spondias purpurea* L.] [3]	0.47 ± 0.06	0.49	0.52	0.39	52
Malay (rose) apple (*Syzygium malaccense* (L.)	1.04 ± 0.12	1.03	1.20	0.90	115

Merr. & L.M. Perry) [3]					
Granadilla (*Passiflora ligularis* Juss) [3]	0.46 ± 0.06	0.45	0.49	0.42	51
Passion Fruit (*Passiflora edulis* Sims) [3]	0.46 ± 0.03	0.77	0.98	0.65	51
Peach Palm (*Bactris gasipaes* Kunth) [3]	0.59 ± 0.01	0.60	0.60	0.57	65
Sweet Lemon (*Citrus limetta* Risso) [3]	0.48 ± 0.06	0.52	0.52	0.40	53
Tacaco (*Sechium tacaco* (Pittier) C. Jeffrey) [3]	1.40 ± 0.05	1.04	1.12	0.95	155
Foods with only one hit, n = 5					
	Concentration, mg/100 g				*%*
Garlic (*Allium sativum* L.) [1, 1.27, 20.00]	0.60				66
Confectionery/candy	0.14				15
Bean [*Phaseolus vulgaris* L.]	0.23				25
Cassava Flour	0.30				33
Coffee mucilage	0.19				21

[a] Numbers in square brackets embody in respective order: the number of samples *n*, percentage represented from the total of samples (i.e., *n* = 190), and percentage represented within each food category. [b] Daily values according to US FDA, 2022 (i.e., 900 µg for copper); mineral input calculated per 100 g food matrix.

Sodium and potassium

Sodium content

An abundant component of extracellular fluids, Na participates in nutrient transport, blood and osmotic pressure regulation, and nerve impulse transmission (Cruz et al., 2011). Daily content needed to achieve normal physiological activities range from 200-500 mg Na (da Silva Amorim Gomes et al., 2021).

In the food industry, employing sodium salts (e.g., Regulation (EC) No 1333/2008 and Commission Regulation (EU) No 1129/2011 lists at least *n* = 190 sodium additives and *n* = 15 chloride-based salts) are used to process, preserve and flavor foods. In addition, they contribute to the water retention capacity, the color of the products, fat capture, and textures (Capuano et al., 2013; Rýdlová et al., 2022; Sun et al., 2021).

Excessive Na consumption shows adverse effects on human health, related to the cardiovascular system, coronary diseases, increases in blood pressure, reduces the concentration of beneficial microbiota in the intestine, as well as favoring some types of autoimmune diseases (Cruz et al., 2011; Rýdlová et al., 2022; Sun et al., 2021).

Ninety percent of the mineral intake in the diet comes from sodium chloride or salt (Rýdlová et al., 2022). Therefore, to reduce its consumption, the World Health Organization Health has recommended 2 g Na day^{-1} (Cruz et al., 2011; da Silva Amorim Gomes et al., 2021; Rýdlová et al., 2022).

Among the non-exclusive strategies to reduce Na consumption are taxation and regulatory requirements that ensure manufacturers make foods low in salt, which may include reformulating products to lower Na components, substituting all or part of NaCl for KCl, $MgCl_2$, and $CaCl_2$ (Cruz et al., 2011). Also, campaigns and programs make the population aware of the health consequences of excess Na and guide them to make more accurate decisions in search of a more balanced diet.

In line with the references above, processed foods contribute to the highest consumption of Na in the diet, particularly sources of salt from prepared foods, pastries, meat products, cheeses, snacks, sauces, and hot sauces. Analogously, table 11 and Figure 2G show that the products that mainly contribute sodium (in addition to salt itself) are meat products such as bread, sausages, biscuits, tuna pâté, chicken, cheese, turkey, ham, chili paste, and with mean values of 673.22, 738.07, 829.41, 949.31, 959.46, 986.08, 1 093.61, 1 208.49, and 2 563.71 mg/100 g, respectively.

Finally, please note that the Na analysis can also be used to assess the purity of salt, whereas a pure compound should have 39.34 g/100 g (i.e., 22.99 g mol^{-1} for Na/58.44 g/mol^{-1} NaCl). According to our data, salt samples' mean values lay at 34.74 ± 1.35 g/100 g (i.e., the average purity of 88.31 %, Table 11, Figure 2G).

Table 11. Sodium content in assorted foods assayed during 2019-2021

Matrix[a]	**Mean ± SD**	**Median**	**Maximum**	**Minimum**	**Daily Value[b]**
	Concentration, mg/100 g				*%*
Meat and meat products, n = 245					
Tuna pâté [100, 10.58, 40.82]	738.07 ± 547.82	538.82	3 096.01	430.71	32
Pâté [66, 6.98, 26.94]	463.94 ± 132.35	447.31	687.52	4.91	20
Sausage [36, 3.81, 14.69]	986.08 ± 178.28	979.76	1 333.58	598.12	43
Ham [20, 2.12, 8.16]	1 208.49 ± 332.72	1 254.69	1 523.26	4.55	52
Meat cuts [13, 1.38, 5.31]	547.60 ± 355.34	526.95	1 256.48	55.58	24
Chicken [5, 0.53, 2.04]	949.31 ± 360.18	858.99	1 644.03	669.94	41

Turkey [3, 0.32, 1.22]	1 093.61 ± 353.83	866.28	1 593.33	821.23	48
Lard [2, 0.21, 0.82]	1.39 ± 1.31	1.39	0.08	2.70	0.06
Dairy and dairy products, n = 118					
Milk powder [34, 3.60, 28.81]	238.34 ± 102.52	198.06	430.43	5.65	10
Matured cheese [23, 2.43, 19.49]	472.53 ± 608.69	291.25	2 505.20	3.11	20
Yogurt [22, 2.33, 18.64]	57.96 ± 28.03	46.82	134.08	25.13	2
Fresh cheese [19, 2.01, 16.10]	959.46 ± 781.12	563.55	2 299.78	121.83	41
Ice cream [8, 0.85, 6.78]	64.81 ± 40.53	51.76	167.33	27.61	3
Whey [7, 0.74, 5.93]	559.72 ± 1 045.76	76.18	3 102.82	22.75	24
Cream cheese [3, 0.32, 2.54]	439.81 ± 68.40	426.10	529.59	363.75	19
Milk [2, 0.21, 1.69]	102.34 ± 47.95	102.34	150.29	54.40	4
Misc, n = 122					
Edible seaweed [11, 1.16, 9.02]	1 011.09 ± 907.83	570.57	2 671.43	11.08	44
Chili paste [5, 0.53, 4.10]	2 563.71 ± 3 014.58	593.90	7 544.36	40.88	111
Cocoa and by-products [25, 2.65, 20.49]	24.07 ± 20.08	19.64	98.62	5.93	1
Coffee [7, 0.74, 5.74]	12.16 ± 14.24	4.99	43.01	0.80	0.5
Breader mix [2, 0.21, 1.64]	673.22 ± 174.33	673.22	847.55	498.89	30
Jam [10, 1.06, 8.20]	17.92 ± 17.13	10.42	60.12	3.74	0.7
Mayonnaise [28, 2.96, 22.95]	705.46 ± 166.39	696.74	1 076.20	411.79	31
Oil [4, 0.42, 3.28]	2.49 ± 1.34	2.52	4.02	0.90	0.1
Rice [2, 0.21, 1.64]	2.68 ± 1.04	2.68	3.72	1.64	0.1
Seasoning [5]	431.45 ± 246.64	355.91	904.84	180.43	19
Salt [3, 0.32, 2.46]	34 742.20 ± 1 348.76	33 788.49	36 649.63	33 788.49	1 510
Assorted nuts [2]	20.67 ± 1.09	20.67	21.76	19.59	1
Snacks [16, 1.69, 13.11]	303.86 ± 144.24	299.92	536.93	4.43	13
Starch [2]	23.25 ± 0.25	23.25	23.50	23.00	1
Beverages, n = 40					
Beverage mix [34, 3.60 85.00]	87.64 ± 200.27	7.32	915.53	1.02	4
Tea [4, 0.42, 10.00]	24.33 ± 29.89	3.42	66.60	2.96	1
Wine [2, 0.21, 5.00]	7.80 ± 4.44	7.80	12.24	3.36	0.3
Bakery and pastry products, n = 125					
Bread [93, 9.84 74.4]	567.91 ± 187.82	585.16	1 000.71	4.35	25
Biscuit [5, 0.53, 4.00]	829.41 ± 174.17	747.94	1 168.91	690.39	36
Cookies [27, 2.86, 21.6]	331.63 ± 200.26	277.72	877.89	89.36	14
Candies & other sweets, n = 16					
Honey [12, 1.27, 75.00]	18.67 ± 38.05	7.05	144.62	4.41	1
Coconut caramel [2, 0.21, 12.5]	11.59 ± 5.02	11.59	16.62	6.57	0.5
Caramel [2]	150.24 ± 3.74	150.24	153.98	146.49	6
Cereals & Pasta, n = 8					
Cereal [3, 0.32, 37.5]	211.66 ± 3.75	211.23	216.45	207.29	9
Pasta [5, 0.53, 62.5]	76.91 ± 147.38	3.19	371.66	2.33	3
Fruits. Vegetables & Others, n = 156					
Bean [62, 6.56, 39.74]	113.93 ± 150.32	29.49	611.79	2.46	5
Tomato [32, 3.39, 20.51]	206.49 ± 266.38	66.54	1 325.74	22.66	9
Dragon fruit [12, 1.27, 7.69]	10.27 ± 2.18	10.75	13.24	4.42	0.4
Corn [10, 1.06, 6.41]	28.62 ± 35.89	7.88	85.30	1.50	1
Banana [5, 0.53, 3.21]	210.57 ± 170.30	242.65	453.16	11.09	9
Mushroom [4, 0.42, 2.56]	160.47 ± 62.47	176.99	228.06	59.86	7
Cashew (*A. occidentale* L.) [3, 0.32, 1.92]	22.86 ± 1.69	21.74	25.25	21.61	1
Sweet granadilla/grenadia (*P. ligularis* Juss) [3]	12.34 ± 4.48	11.08	18.34	7.59	0.5
Granola [3]	289.22 ± 267.61	199.81	652.40	15.44	12
Jocote (*Spondias purpurea* L.) [3]	2.15 ± 0.72	2.29	2.96	1.20	0.09
Passion fruit [3]	60.88 ± 14.25	56.81	80.01	45.81	3
Peach-palm [3]	935.86 ± 12.18	940.92	947.58	919.06	40
Sweet lemon (*C. limetta* Risso) [3]	21.82 ± 3.95	22.53	26.27	16.66	1
Tacaco (*Sechium tacaco* (Pittier) C. Jeffrey) [3]	7.34 ± 0.29	7.47	7.61	6.93	0.3
Malay (rose) apple [3]	42.31 ± 12.92	45.20	56.49	25.24	2
Onion [2, 0.21, 1.28]	718.32 ± 157.74	718.32	876.06	560.58	31
Sweet pepper [2]	10.07 ± 0.12	10.07	10.19	9.95	0.4
Flours and meals, *n = 71*					
Wheat meal [59, 6.24, 83.10]	3.24 ± 2.26	2.71	13.55	0.91	0.1
Corn meal [8, 0.85, 11.27]	35.22 ± 20.59	31.37	79.07	12.01	1
Banana meal [2, 0.21, 2.82]	13.31 ± 6.88	13.31	20.19	6.42	0.6
Cassava meal [2]	18.14 ± 4.84	18.14	22.98	13.30	0.8
Seafood, *n = 24*					
Sardine [2, 2.22, 87.5]	530.94 ± 51.56	530.94	582.51	479.38	23
Tuna [3, 0.32, 12.5]	389.33 ± 97.53	393.64	506.57	267.79	17

Foods with only one hit, *n = 20*		
	Concentration, mg/100 g	*%*
Cake [1, 0.11, 5.00]	297.97	13
Candy	80.63	3
Cassava	348.12	15
Coconut	15.72	0.6
Corn cake	388.34	17
Garlic	78.37	3
Egg	136.00	6
Malta	34.29	1
Marshmallows	10.12	0.4
Coffee mucilage	54.97	2
Pancakes	712.91	31
Pignut/chan seeds (*M. suaveolens* (L.) Poit.)	12.56	0.5
Sauce	464.85	20
Shrimp	42.98	2
Soy milk	212.54	9
Strawberry	4.68	0.2
Sugar	1.06	0.05
Sugar cone	247.77	11
Syrup	19.40	0.8
Tartar sauce	589.79	26

[a]Numbers in square brackets embody in respective order: the number of samples *n*, percentage represented from the total of samples (i.e., *n* = 190), and percentage represented within each food category. [b]Daily values according to US FDA, 2022 (i.e., 2 300 mg for sodium); mineral input calculated per 100 g food matrix.

Potassium content

The foods with the most K are tomato and orange, with mean values of 3 269.31 and 1 020 mg/100 g, respectively (Table 12, Figure 2H). The intake of K per day should be approximately around 3 500-4 700 mg (US FDA, 2022). In addition, levels of K are among those with the most variability (i.e., 65-3 269 mg/100 g, Table 11). Foods with lower concentrations include tea and starch (7.17 and 5.58 mg/100 g, respectively, Table 11).

Dairy products also exhibited a relatively high concentration of K (e.g., yogurt and milk powder with mean values of 159.30 and 620.08 mg/100 g, respectively, Table 12, Figure 2H). In contrast, levels of K for northern Italy milk around 154.72 mg/100 g have been reported; likewise, the authors found that K was the mineral with the highest concentration overall (Vigolo et al., 2022). Several studies have shown that the concentrations of K and Na in milk are directly related to the supplements given to cattle, where the amount of mineral fortification in the diet depends on the region (Stergiadis et al., 2019).

The highest K concentrations are found in fruits and vegetables (e.g., tomato, tacaco, orange, Malay (rose) apple, jocote, cocoa, and seaweed, Table 12, Figure 2H). Accordingly, in the US, the ten foods that contain the highest amount of K have been studied, and these are shown to be fruits, vegetables, and milk (Sebastian et al., 2018). In Costa Rica, there is a greater consumption of vegetables than fruits. Nevertheless, the most consumed are tropical, subtropical, and citrus fruits (Gómez et al., 2021). People in this country consume about 220.1 g of vegetables and fruits daily, an average below WHO recommendations of at least 400 g (Gómez et al., 2021). Regular consumption of K may provide health benefits as it reduces cardiovascular problems produced by Na because it works as a vascular protector (Sebastian et al., 2018).

Table 12. Potassium content in assorted foods assayed during 2019-2021

Matrix[a]	**Mean ± SD**	**Median**	**Maximum**	**Minimum**	**Daily Value[b]**
	Concentration, mg/100 g				*%*
Dairy and dairy products, n = 36					
Milk powder [22, 61.11, 11.58]	620.08 ± 289.19	480.54	1 684.82	405.44	13
Cheese [10, 27.78, 5.26]	82.78 ± 26.41	75.13	136.43	41.25	2
Yogurt [4, 11.11, 2.11]	159.30 ± 31.71	149.08	209.10	129.96	3
Misc, n = 95					
Cocoa [*Theobroma cacao* L.] [23, 24.21, 12.11]	1 505.49 ± 606.38	1 641.49	2 386.07	74.41	32
Powdered drinks [19, 20.00, 10.00]	72.71 ± 72.17	52.02	233.31	0.17	2
Crackers [10, 10.53, 5.26]	201.89 ± 92.66	69.39	400.39	198.53	4
Edible seaweed [7, 7.37, 3.68]	1 631.31 ± 1 396.77	1 069.24	4 962.04	623.59	35
Ham [7]	65.47 ± 69.86	36.90	233.73	20.85	1

Cornmeal [6, 6.32, 3.16]	390.28 ± 35.14	380.66	440.53	347.59	8
Breakfast cereal [3, 3.16, 1.58]	95.51 ± 9.10	92.99	107.71	85.84	2
Bean (*Phaseolus vulgaris* L.) [3]	344.99 ± 84.65	382.37	424.790	227.81	7
Honey [3]	70.94 ± 49.03	47.31	139.21	26.31	2
Candy [2, 2.11, 1.05]	252.50 ± 12.84	252.50	265.34	239.65	5
Caramel [2]	326.16 ± 6.70	326.16	332.85	319.46	7
Cassava flour [2]	819.38 ± 100.02	819.38	919.40	719.36	17
Pasta [2]	369.98 ± 180.84	369.98	550.82	189.14	8
Pepper [2]	351.80 ± 219.25	351.80	571.05	132.55	7
Starch [2]	5.58 ± 0.63	5.58	6.21	4.95	0
Tea [2]	7.12 ± 0.52	7.17	7.69	6.65	0
Fruits, n = 51					
Tomato (*Solanum lycopersicum* Lam) [21, 41.18, 11.05]	3 269.31 ± 790.86	311.71	4 309.38	790.86	70
Dragon fruit (*H. costaricensis* (F.A.C. Weber) Britton & Rose) [9, 17.65, 4.74]	269.19 ± 32.11	269.39	331.70	217.77	6
Cashew (*Anacardium occidentale* L.) [3, 5.88, 1.58]	707.38 ± 167.10	760.87	877.26	430.52	15
Granadilla (*Passiflora ligularis* Juss) [3]	1 858.90 ± 27.12	1 840.88	1 897.23	1 838.59	40
Jocote (*Spondias purpurea* L.) [3]	1 157.22 ± 39.11	1 181.94	1 187.71	1 102.01	25
Malay (rose) apple (*Syzygium malaccense* (L.) Merr. & L.M. Perry) [3]	1 566.74 ± 466.60	1 296.44	2 223.21	1 180.56	33
Peach Palm (*Bactris gasipaes* Kunth) [3]	617.25 ± 36.50	620.67	660.16	570.94	13
Sweet Lemon (*Citrus limetta* Risso) [3]	1 322.22 ± 48.17	1 294.92	1 389.92	1 281.81	28
Tacaco (*Sechium tacaco* (Pittier) C. Jeffrey) [3]	2 332.73 ± 89.45	2 295.30	2 456.10	2 246.79	50
Foods with only one hit, n = 8					
	Concentration, mg/100 g				*%*
Dressing [1, 12.5, 0.53]	87.13				2
Rice	186.97				4
Coffee	167.76				4
Onion	237.51				5
Pepper	183.29				4
Whole egg	117.20				2
Marshmellows	70.29				1
Orange (*Citrus sinensis* (L.) Osbeck)	1 020.55				22

[a]Numbers in square brackets embody in respective order: the number of samples *n*, percentage represented from the total of samples (i.e., *n* = 190), and percentage represented within each food category. [b]Daily values according to US FDA, 2022 (i.e., 4 700 mg for potassium); mineral input calculated per 100 g food matrix.

Further remarks: Mineral profile and nutritional fulfillment

Deficits in micronutrients, such as Ca, Fe, and Zn, are common in home-based complementary diets fed to young children in developing countries. Food composition data (including the above mineral ingredients) has been used in formulating complex diets for children, including consistency and economic constraints (De Carvalho et al., 2015). Furthermore, mineral profiling results extremely useful in, for example, the preparation and formulation of diets for patients with specific afflictions (e.g., hyposodic diets tailored for heart failure or chronic kidney disease, Borelli et al., 2020; Patel and Joseph, 2020; Solis et al., 2010) and including nutritional-epidemiologic studies (Byers, 1999). A small Costa Rican study demonstrated that 22% of a population sample aged 15 and above suffered from hypertension (Zumbado Sánchez and Zumbado Ulate, 2011).

The mineral composition is required for food-guaranteed labeling (such as front-of-pack nutrition labels). Food labeling is a consumer guide toward healthier food choices and comprehensive strategies to prevent diet-related non-communicable diseases (Egnell et al., 2019; Jones et al., 2019). In Costa Rica, the technical regulation (RTCA 67.01.60:10, "Nutritional Labeling of Prepackaged Food Products for Human Consumption for Population from 3 years"), which is voluntary, requires only the report of Na; the yearly increase of other minerals analysis probably corresponds to the industry's export needs. This is reflected in the food industry's requirements and, more importantly, increased interest in their products and raw ingredients. For example, annual trends in figure 1A demonstrate that analysis requests for some minerals have risen as high as 40% from one year to another (e.g., Ca and Zn, Figure 1B).

On the other hand, Table 13 shows the analysis of the mineral profile provided by a typical Costa Rican meal such as Gallo Pinto, which is widely consumed by the Costa Rican population at breakfast time, as well as at lunch and dinner. Describing the mineral profile of Gallo Pinto allows us to analyze and visualize the mineral consumption by the Costa Rican population. The table first shows the distribution of each mineral by ingredient and the total global mineral contribution by the meal at the end. In the case of P, in a single meal time, more than

50% of the recommended daily values were consumed, in contrast to the Ca values, which generate a Ca:P ratio below the recommended 1.7 (Gutierrez et al., 2020). However, Ca is the mineral most consumed by the Costa Rican population, in part due to the high consumption of dairy products in Costa Rica (217 kg per capita), as well as the enrichment and fortification programs with this mineral (Monge-Rojas et al., 2021) (National Council of Milk Producers., 2017). P sources, in this case, are primarily of plant origin, so P bioavailability analyses should be carried out.

Another interesting fact is the contribution of Cu (90.19%) in a single meal time, which can be counterproductive as it is a mineral that competes with Zn in intestinal absorption (Vinha et al., 2019). The remaining minerals maintain expected values, considering that a single meal time was analyzed. Therefore, it is possible to comply with the recommended daily consumption values throughout the day.

Table 13. Description of the mineral profile of Gallo Pinto with coffee

Gallo Pinto & Coffee		**Mineral Profile mg per serving (% Daily Value)**							
Ingredients	**1 Serving (g)**	**Ca**	**P**	**Mg**	**Fe**	**Zn**	**Cu**	**Na**	**K**
Rice	112.50	27.00[a]	332.92	22.50[a]	1.08	1.46[a]	0.20	3.02	210.34
		(2.08)	(26.63)	(5.36)	(5.98)	(13.30)	(22.50)	(0.13)	(4.48)
Beans	75.00	47.66	93.53[b]	32.25[b]	2.44	0.68	0.17	85.45	258.74
		(3.67)	(7.48)	(7.68)	(13.54)	(6.14)	(19.17)	(3.72)	(5.51)
Garlic	10.00	4.35	47.27	10.02	0.28	0.34	0.06	7.84	4.88[c]
		(0.33)	(3.78)	(2.39)	(1.56)	(3.10)	(6.67)	(0.34)	(1.10)
Onion	10.00	2.03	30.92[d](2.47)	8.62[d]	0.41	0.27[d]	0.25[d]	71.83	23.75
		(0.16)		(2.05)	(2.27)	(2.44)	(27.48)	(3.12)	(0.51)
Sweet pepper	10.00	10.41[e]	17.04[e]	1.20[e]	0.74[e]	0.19[e]	0.08[e]	1.01	0.33[e]
		(0.80)	(1.36)	(0.29)	(4.09)	(1.69)	(8.82)	(0.04)	(0.01)
Salt	1.50	0.00	0,00	0.00	0.00	0.00	0.00	521.13	0.00
								(22.66)	
Whole egg	100.00	56.52	179.00[f]	0.03[f]	1.94	1.12[f]	0.05[f]	136.00	117.20
		(4.35)	(14.32)	(0.01)	(10.76)	(10.18)	(5.56)	(5.91)	(2.49)
Coffee	15.00	0.94	32.31[g]	32.01[g]	0.05	0.15[g]	NI	1.82	25.16
		(0.07)	(2.59)	(7.62)	(0.28)	(1.35)		(0.08)	(0.54)
TOTAL	**334.00**	**148.90**	**732.98**	**106.63**	**6.93**	**4.20**	**0.81**	**828.10**	**640.40**
		(11.45)	**(58.64)**	**(25.39)**	**(38.48)**	**(38.20)**	**(90.19)**	**(36.00)**	**(13.63)**

Carcea (2021)[a], Dhul et al., (2021)[b], Khan et al., (2016)[c], Akinwande and Olatunde (2015)[d], Guilheerme et al., (2020)[e], Roe et al., (2013)[f], Janda et al., (2020)[g]. Calculation of the mineral contribution according to Daily Values US FDA, 2022.

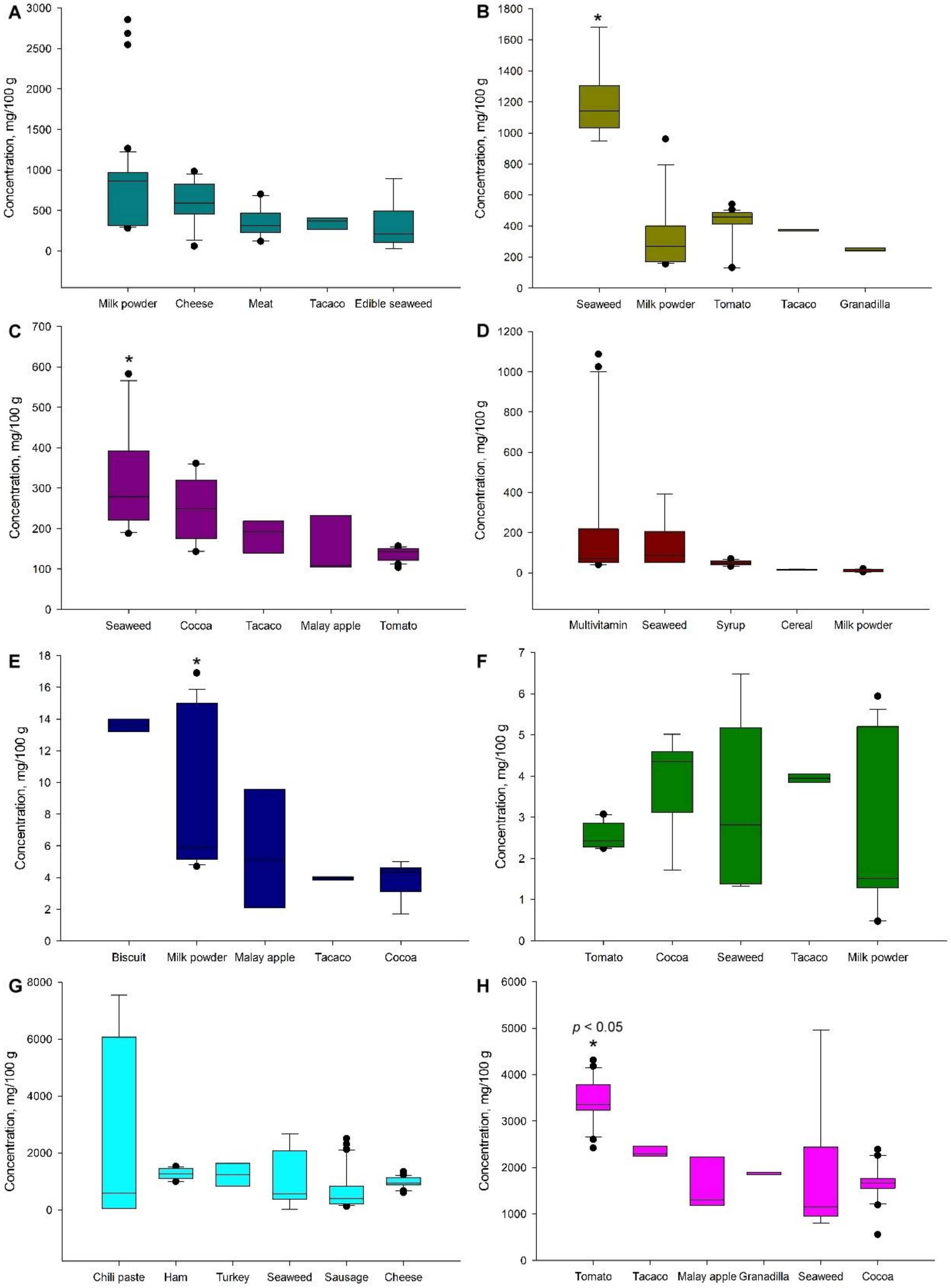

Figure 2. Mineral trends and comparison for food matrices with the highest analyte levels for A. Calcium, B. Phosphorus, C. Magnesium, D. Iron, E. Zinc, F. Copper, G. Sodium, and H. Potassium. Asterisks denote significant differences at $p < 0.05$

4. Conclusions

With nutritional information, additional efforts must be made to attain knowledge regarding the consumption behavior for products listed herein, especially those with high mineral input on a diet. Perspective data, such as this, provides composition data and aids in understanding consumption and production behavior. In the case of fruits, it shows instances of biodiversity and may hint toward Costa Rican main exports. Knowing the concentrations of minerals in foods will aid in balancing their consumption. Additionally, the routine analyses of the nutritional profile of foods in general, and specifically on micronutrients, allows for maintaining food quality control, complying with current legislation on minimum dietary content, as well as on enrichment and fortification programs of defined food groups (such as flours, dairy products, cereals, rice, among others). Furthermore, having at hand the nutritional information of the types of foods of a population, as well as their composition and consumption, allows social and political decisions to be made at the country level to combat malnutrition in people at risk, as is the case of Ca, Mg, Fe, and Zn, essential in the early stages of life. Finally, direct the food industry and the population to reduce sodium consumption in food, promote better health, and combat chronic diseases, which in the long term, generate expenses in the health system.

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