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SAFETY IN CONSUMPTION OF THE UNRIPE AND RIPE BANANAS, IN NATURE AND DEHYDRATED, EVALUATED BY ENERGY-DISPERSIVE X-RAY FLUORESCENCE TO DETERMINE THE ELEMENTAL CHEMICAL COMPOSITION

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ABSTRACT
Bananas, both "in nature" and dehydrated, were examined at ripening stages 1 and 7 using an oven and were analyzed by energy-dispersive X-ray fluorescence (EDXRF) technique facilitated the elemental analysis. This investigation established an experimental protocol for the EDXRF analysis of bananas, yielding empirical data on their elemental nutritional content. Consequently, the elemental concentrations in the silver banana (Musa spp.) may correlate with its maturity and hydration state. Additionally, it was observed that beyond the macro and micronutrients present, bananas contain impurities and heavy metals, warranting caution in their consumption. Discussions encompassed the daily intake limits of silver bananas, their toxicological safety based on experimental data, and the implications for human consumption of this pseudo-fruit.

Keywords: Banana. EDXRF. Elemental Analysis. Food Safety. Nutritional Content.

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INTRODUCTION

The “in nature” bananas play a significant social and economic role in Brazil, the world's largest consumer of this pseudo-fruit and the fourth-largest producer globally, with an annual production of 6.6 million tons on 455 thousand hectares. The banana agribusiness generates approximately R$13.8 billion and 500 thousand direct jobs in the country.[1]

Despite these impressive numbers, Brazilian banana exports are limited, with most being consumed “in nature” and a small portion industrialized for the domestic market. This low export rate is attributed to a need for more technology for quality control and transportation efficiency.[1]

Pereira et al.[2] and Sperança et al.[3] in previous studies have conducted elemental analysis of bananas using energy-dispersive X-ray fluorescence (EDXRF) technique but challenges arose with equipment parameterization and sample preparation. Understanding nutrient concentrations in bananas is particularly important due to their high consumption in Brazil.

Banana plants primarily absorb potassium (K), nitrogen (N), calcium (Ca), and magnesium (Mg) from the soil, among other elements.[1,4] This knowledge underlines the need to investigate how these nutrients vary with the pseudo-fruit's ripening stage and dehydration state.

This study explores how bananas' ripening stage and dehydration state influence their elemental composition, given Brazil's prominent role in banana production and consumption. Using the EDXRF technique, we assess the hypothesis that bananas' elemental makeup differs based on ripening and dehydration levels. Our findings yield insights into nutritional elements that could enhance the value of dehydrated bananas. Additionally, we developed an experimental protocol for analyzing bananas and provided comparative data between fresh and dehydrated (ripe and unripe) bananas, establishing guidelines for adequate daily nutrient intake.

METHODOLOGY

RAISIN BANANA PRODUCTION

The production method described by Pereira et al.[3] was used with adaptations from authors Batista et al. [5], Padilha et al. [6], and Stringheta et al.[7]. Sixteen bananas at stage 7 of ripeness (gross weight of 2.765 kg) and 16 at stage 1 (gross weight of 2.215 kg) were used,

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along with latex gloves, disposable masks, parchment paper, a drying oven with circulating air (Fame®, 520/3-C, Brazil), a granular balance (Matte®, AS 2000, Brazil), amber glass bottles with caps, polyethylene plastic bags, plastic trays, citric acid, ascorbic acid, and vacuum packaging equipment (Engaged®, SUV308, Italy).

Initially, the bananas were immersed in chlorinated water (50 ppm concentration) for 30 min, then rinsed and immersed in an antioxidant solution containing 4% citric acid and 1% ascorbic acid for 5 min , reproducing the Mota [8] technique. Afterward, the bananas were removed, weighed, numbered, and placed on trays. They were then immediately put in a drying oven at 70 ± 3 ºC, with an air velocity of 3 m/s, for 12 h. After drying, the pseudo-fruits were cooled for 15 min. The bananas were vacuum-packed in plastic bags and stored in a refrigerator for 10 days for moisture uniformity, as suggested by Stringheta et al.[7]

BANANA MOISTURE CONTENT ANALYSIS

The mass balance analysis quantified the moisture loss in the circulating air oven by weighing the bananas before and after desiccation. The resultant mass difference represented the percentage of water evaporated.

SAMPLE PREPARATION FOR ELEMENTAL ANALYSIS

The sample preparation method followed Caldana et al.[9] with modifications. Pressed tablets were made using 160 g of cellulose-derived powder (227833, 08/31/2021, Taiwan), disposable gloves and masks, a grain grinder (Black & Decker, MG200-B2, China), a granary scale, an AMEF hydraulic press (AP-25T, Brazil), plastic bottles with lids, and trays. Bananas were individually ground for 3 min, with two pauses for mechanical mixing using a stainless-steel spatula.

Due to varying banana textures, cellulose powder was added to facilitate compression, with tests determining the standard cellulose-to-banana ratio for each 1.5 g of banana: 0.5, 1, 1.5, 2, 2.5, 3, 3.5, and 4 g of cellulose. After homogenizing in the grinder, a hydraulic press applied 5.0 t cm^{-2} for 10 s to form tablets. These were analyzed for strength, moisture, and homogeneity. The final tablet mass was set at 4 g, comprising 1.5 g of banana sample and 2.5 g of cellulose, a consistent concentration used throughout.

Each processed banana sample of 1.5 g was placed in labeled plastic containers according to condition ("in nature" or dehydrated) and ripeness (1 or 7). The grinder was cleaned between each sample to prevent cross-contamination.

The homogenization took 180 s with two 60 s pauses, and samples were stored according to their state and ripeness. The resulting tablets were solid and cohesive enough to withstand laser-induced plasma expansion, enhancing the precision and reproducibility of measurements.[10]

Each sample was weighed and pressed into a round tablet; approximately 30.15 mm in diameter and 4.36 mm in height, using 5.0 t cm^{-2} for 10 s. Non-cohesive tablets were remade. Finished tablets were stored in plastic containers with lids and ready for analysis.

ELEMENTAL ANALYSIS OF BANANAS USING THE EDXFR TECHNIQUE

Measurements were performed using a benchtop EDXRF spectrometer (Malvern®, Epsilon 1, United Kingdom) equipped with a 5 W X-ray tube, 10–50 kV Ag anode, with an energy resolution of 125 eV. The spectrometer had a high-resolution Silicon Drift Detector operating under atmospheric pressure.

RESULTS

MOISTURE CONTENT OF SAMPLES

The Shapiro-Wilk test was performed on the dehydration essays' data to evaluate whether the moisture distribution resembles a normal distribution. The results indicated that the sample masses follow a normal distribution, with a W statistic yielding a significance value of $p<0.05$. Consequently, an independent samples t-test was deemed appropriate.

Table 1 presents the t-test results for independent samples. It showed a significant difference ($p<0.01$) between the gross mass at the initial time (t_0) and the moisture lost after drying the ripe and unripe bananas, with ripe bananas exhibiting a more significant loss of moisture than unripe ones.

Table 1 - Results of the t-test for independent samples

Evaluated parameter	**Gross mass (g) t_0**		**Moisture lost (%)**	
Ripening	Ripe	Unripe	Ripe	Unripe
Size	17	18	17	18
Average	112.7041	90.2539	58.6400	48.7813
Variance	115.1931	276.1955	14.2557	9.6110
	Homoscedasticity	---	Homoscedasticity	---
Variance	198.1337	---	11.8630	---
t	4.7159	---	8.4635	---
Degrees of freedom	33	---	33	---
p (one-sided)	< 0.0001	---	< 0.0001	---

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p (bilateral)	< 0.0001	---	< 0.0001	---
Power (0.05)	0.9990	---	1.0000	---
Power (0.01)	0.9921	---	1.0000	---
Difference between averages	22.4502	---	9.8587	---
95% CI (Difference between means)	12.7636 a 32.1369		7.4884 a 12.2289	
99% CI (Difference between means)	9.4344 a 35.4661	---	6.6738 a 13.0435	---

Legend: Confidence interval (CI). Calculated in the BioEstat 5.3 software.

Ripe bananas exhibited an average initial mass of 112.7 g, which decreased to a dry mass of 66.23 g post-desiccation, yielding an average moisture loss of 58.64 %. In contrast, unripe bananas had an average initial mass of 90.25 g and a final dry mass of 43.98 g, resulting in an average mass loss of 48.78% per banana (Table 1).

EDXRF ELEMENTAL ANALYSIS

Each tablet was analyzed using EDXRF equipment per the previously outlined specifications, lasting 50 min per sample. The elements magnesium (Mg), phosphorus (P), aluminum (Al), arsenic (As), and scandium (Sc) were not detected. This analysis yielded the concentrations, expressed in μg g^{-1}, of 32 elements across the 64 samples.

To facilitate interpretation, we calculated the average ($\bar{x}$) and standard deviation (***s***) of the concentrations (μg g^{-1}) for each element (n=3). The resulting data were categorized into four groups based on maturity and hydration state: “in nature” ripe (A), “in nature" unripe (B), dehydrated ripe (C), and dehydrated unripe (D) bananas (see Table 2).

Table 2 - Data of concentration (μg g^{-1}) from the elemental analysis of the “in nature” ripe (A), “in nature" unripe (B), dehydrated ripe (C), and dehydrated unripe (D) bananas

Element	A		B		C		D	
	$\bar{x}$	*s*	$\bar{x}$	*s*	$\bar{x}$	*s*	$\bar{x}$	*s*
Ti	4.1	2.8	7.6	2.6	6.9	4.3	6.03	1.5
V	3.4	1.8	3.5	2	3.6	2.7	3.6	2.1
S	440.7	46.0	533.6	49.9	575.1	68.0	655.2	63.2
Cl	2250.0	120.8	2255.5	107.5	3300.3	103.2	3559.1	312.2
Ca	654.7	109.2	625.0	40.3	713.7	53.0	733.3	61.0
Mn	49.1	22.8	54.9	22.6	62.9	13.7	64.5	26.0
Fe	300.4	23.2	289.4	27.2	348.1	40.8	152	28.6
Cu	10.5	1.7	11.9	2.9	14.5	5.2	16.4	8.4
Zn	5.9	0.9	5.2	0.8	9.2	1.0	9.9	1.3
Pd	3.7	2.2	4.3	3.1	3.4	2.0	5.9	2.0
Sr	2.6	0.6	2.7	0.6	3.3	0.7	3.4	0.5
K	8522.0	438.4	9701.1	471.6	17920.3	1510.6	17155.3	2388.0

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Si	2146.7	162.7	2614.3	158.8	2001.5	190.4	2012.5	304.5
Y	5.1	0.7	4.9	0.6	4.6	0.6	4.7	0.7
Zr	8.4	1.0	9.0	0.8	9.1	0.5	9.1	0.9
Nb	9.8	1.0	9.7	0.8	9.6	0.9	9.8	0.8
Cr	17.4	5.9	17.9	4.4	17.3	3.1	20.0	5.6
Co	88.3	70.1	119.1	59.5	102.8	70.0	99.4	78.1
Ni	4.4	1.3	4.7	1.7	6.6	1.7	4.3	1.5
Mo	8	0.8	8.4	1.1	8.9	0.8	9.2	1.3
Br	0.5	0.3	0.9	0.5	0.5	0.3	2.2	0.4
Rb	2.7	0.4	4.7	0.7	4.8	0.8	10.2	1.0
Tc	0.9	0.7	0.9	0.5	0.7	0.4	1.0	0.4
Ru	0.5	0.4	0.5	0.3	0.5	0.4	0.8	0.5
Ag	1515.0	19.9	1444.0	20.6	1501.2	18.6	151.6	23.8
Au	0.7	0.4	0.6	0.7	0.7	0.7	0.5	0.6
Bi	2.1	0.7	1.8	0.5	1.8	0.7	1.7	0.6
Cd	11.7	4.0	10.5	2.9	10.8	2.2	11.2	3.1
In	4.1	1.0	3.1	1.6	3.5	1.5	3.8	2.0
Sn	32.8	9.3	35.5	3.3	37.9	8.7	40.2	10.6
Sb	22.4	4.7	19.7	4.9	19.8	3.7	21.1	4.2
Hf	2.4	1.3	2.2	1.7	2.9	1.4	1.9	1.7

DISCUSSION

The EDXRF technique helps us understand the elements present in this widely eaten pseudo-fruit. Bananas are valued for their taste and nutritional significance and play a crucial role in global diets (HOWARD; HOLLEY; WARNER, 1955). Despite being recognized for their importance, further research into the detailed chemical composition of bananas could influence daily dietary recommendations. This study addresses this gap by investigating silver bananas at two stages of ripening, including dry and fresh samples.

Silva Júnior et al. (2010, p. 25) studied the macronutrients and micronutrients absorbed by banana plants. They found that the most absorbed macronutrients, in descending order, were potassium (K), nitrogen (N), calcium (Ca), magnesium (Mg), sulfur (S), and phosphorus (P). The most absorbed micronutrients, also in descending order, were chlorine (Cl), manganese (Mn), iron (Fe), zinc (Zn), and copper (Cu). Our investigation identified the macronutrients K, Ca, and S and the micronutrients Cl, Fe, Mn, Cu, molybdenum (Mo), and Zn using the adopted technique (see Table 2).

According to the ICH Q3D[10] classification, impurities belonging to class 1 (As, Cd, Hg and Pb) and class 2A (Co, Ni, V) are highly toxic to humans, with those in class 1 being the most toxic with controlled maximum daily intake limits. For the elements in class 1 generally

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called heavy metals, only Cd was observed in this work, with an average concentration of around 11 μg g^{-1}. According to the Brazilian Pharmacopoeia[11], the maximum permitted limit for oral intake of Cd is 0.5 μg g^{-1}, with the result obtained in this study approximately being 22 times above the permitted limit.

For class 2A elements, the Brazilian Pharmacopoeia does not define a limit for Co, but for the elements vanadium and nickel, the limit for both is 25 μg g^{-1}.[11] Our work found values much lower than the maximum limit allowed by the Brazilian Pharmacopoeia for the ingestion of these elements.

It is important to note that we conducted sample production and analysis separately for all 64 bananas. This procedure was necessary because bananas are organic products with a limited shelf life. To ensure that our samples were in optimal condition and to prevent spoilage from affecting the results, we produced the tablets shortly before conducting fluorescence (EDXRF) analysis for each batch of samples.

Studying pseudo-fruits at two different ripening stages helps us understand how their chemical composition changes as they ripen. Additionally, comparing dehydrated and fresh bananas can give us insights into how processing affects the chemical makeup of the pseudo-fruits. This research adds to our knowledge of bananas' elemental composition and explores their safety for consumption.

GENERAL COMPOSITION

The elements titanium (Ti), vanadium (V), palladium (Pd), zirconium (Zr), niobium (Nb), strontium (Sr), yttrium (Y), nickel (Ni), rubidium (Rb), technetium (Tc), silver (Ag), gold (Au), tungsten (W), and indium (In) do not play a known biological role in metabolic processes or bodily functions. Furthermore, they were found in low concentrations (< 10^{-5} mg g^{-1}) in the samples of this study (Table 2).

There is no direct evidence that strontium is toxic to humans. However, epidemiological studies suggest that high oral doses of strontium can be toxic to humans under certain conditions. Stable strontium has relatively low toxicity and makes up about 4.6 μg g^{-1} of the human body. However, it does not have a recognized essential biological role. Human exposure to strontium mainly occurs through oral intake, such as consuming fruits, vegetables, and drinking water, although inhalation exposure is also possible.[12] The average strontium content in this study was 2.6±0.6 μg g^{-1} for ripe bananas "in natura", 2.7±0.6 μg g^{-1} for green bananas "in natura", 3.3±0.7 μg g^{-1} for dehydrated ripe bananas,

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and 3.4±0.5 μg g^{-1} for dehydrated green bananas (see Table 2). Therefore, it is possible to conclude that bananas do not contain toxic levels of strontium.

According Favero, Ribeiro, and Aquino,[13] the elements sulfur (S), chlorine (Cl), and calcium (Ca) play essential roles in the human body, with RDI of approximately 700 mg of sulfur and 1000 mg of chlorine and calcium. However, the concentrations of these nutrients in bananas are low compared to these recommendations. For example, an 80 g silver banana contains 39 mg of sulfur in its "in nature" form and 49 mg when dehydrated — values calculated from the data in Table 2 —. Therefore, bananas do not completely meet the daily requirements for these nutrients, which suggests no concern regarding excessive intake of these compounds through banana consumption. The average concentrations of sulfur, chlorine, and calcium found in bananas were 0.55 mg g^{-1}, 3.04 mg g^{-1}, and 0.68 mg g^{-1}, respectively. Additionally, although there is a slight variation in calcium levels among banana types, sulfur and chlorine concentrations are higher in dried bananas (Table 2). When quantifying chlorine, we must consider that the bananas were initially placed in chlorinated water for a period of 30 min, and this procedure may have affected the result obtained for chlorine present in the bananas.

Bananas are an excellent source of potassium, a medium-sized banana providing 10 % of the daily value.[14] A potassium-rich diet may help reduce blood pressure and lower the risk of hypertension.[15] Potassium RDI for adults should be 700 mg daily, with no established upper limit for this mineral according ANVISA.[11,16] The data obtained in this investigation show a significant difference in potassium concentration between "in nature" and dehydrated bananas, with dehydrated bananas containing nearly double the potassium content (see Graph 1).

An average silver banana weighing 80 g has a potassium content of approximately 728 mg in the "in nature" form and 1,403 mg when dehydrated (see Graph 1). Consequently, consuming dehydrated bananas would be more effective for individuals aiming to increase their potassium intake.

Graph 1 shows that the product type ("in nature" or dehydrated) significantly influences the potassium concentration more than the banana ripening stage. Furthermore, the ripening stage has minimal or no impact on potassium concentration, while the product type significantly increases it. Additionally, there is an interaction between the ripening stage and the product type.

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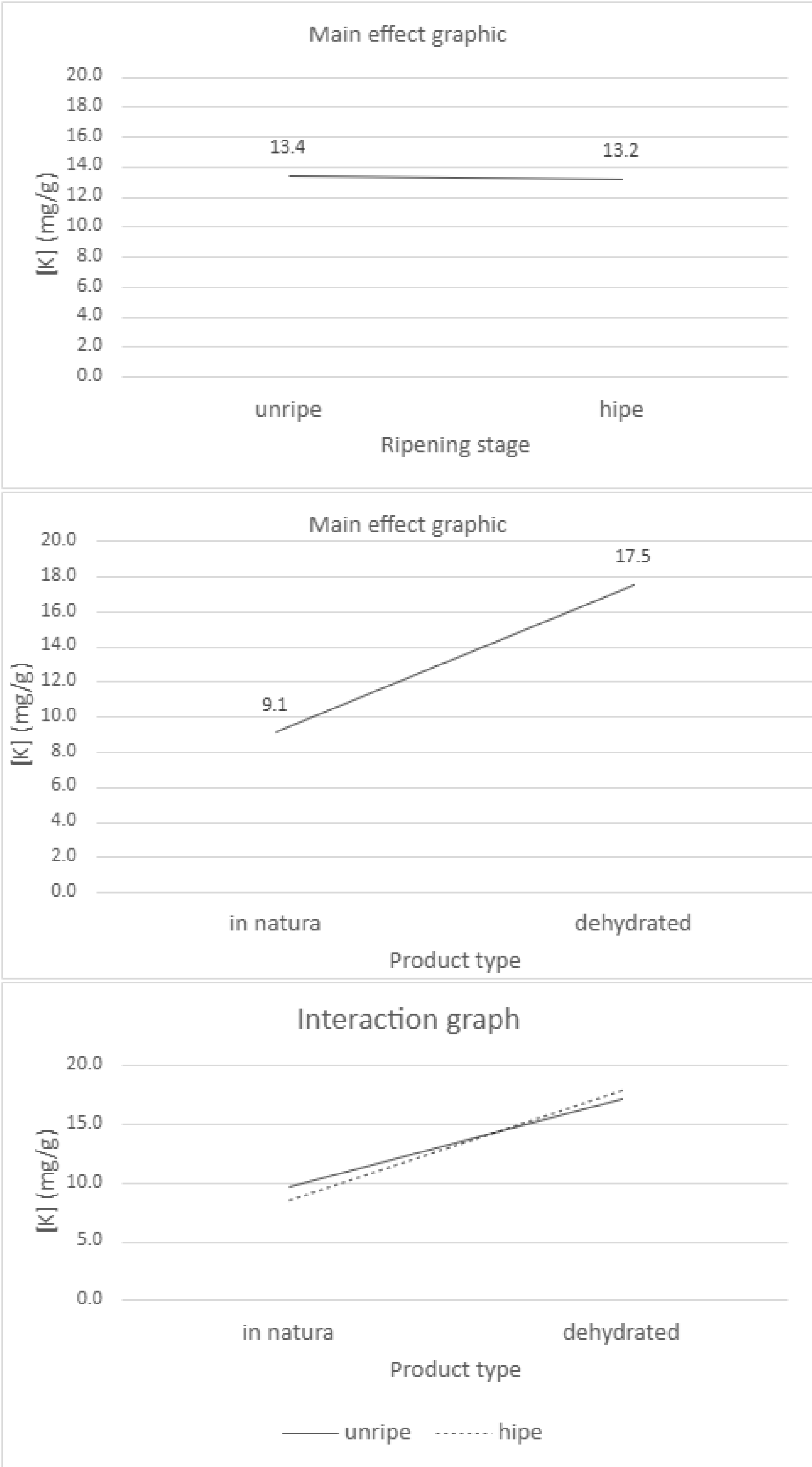
Graph 1 – Graphics of the main effects and interaction effects of the ripening stage and product type on potassium concentration



TRACE ELEMENTS

Chromium (Cr) is essential for biological functions, and its deficiency is linked to several adverse effects. The recommended daily intake of chromium varies from 0.05 to 0.2

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mg, with a maximum permitted value of 500 mg (BRASIL, 2019). In our studies, bananas presented an average concentration of 18 μg g^{-1} of chromium (among the four groups studied), with no variation between the types of bananas analyzed. Considering an 80 g banana, each unit contains approximately 1.45 mg of chromium, which is within the recommended daily amount of this mineral, according to the Brazilian Pharmacopoeia.[11]

Copper (Cu) is necessary for the human body, with a daily RDI of 12.5 μg kg^{-1}, equating to about 0.9 mg daily for a 70 kg adult. Toxicity occurs only after consuming 35 mg daily.[11,16] Silver bananas contain an average of 13.3 μg g^{-1} of copper, showing minimal variation among samples. An 80 g banana provides approximately 1.066 mg of Cu, satisfying the daily requirement. An 80 g banana provides approximately 1.07 mg of copper, meeting the recommendation for RDI.[11,16] The dehydration process concentrates the amount of copper in bananas, as demonstrated in our experiment: from 0.5±1.7 μg g^{-1} and 11.9±2.9 μg g^{-1} in "in nature" to 14.5±5.2 μg g^{-1} and 16.4±8.4 μg g^{-1} in dehydrated bananas.

Zinc (Zn) is used in many physiological processes, including the production of insulin, an essential substance for the human body. The daily RDI for zinc is 8 to 11 mg, with a daily limit of 40 mg to avoid toxicity.[10,11] The average zinc found in bananas was 5.2 μg g^{-1} in “in nature" unripe bananas, 5.9 μg g^{-1} in "in nature" ripe bananas, 9.9 μg g^{-1} in dehydrated unripe bananas and 9.2 μg g^{-1} in a dehydrated ripe banana. It is possible to notice that dehydrated bananas have a higher zinc concentration. Considering an 80 g banana, one unit has between 0.41 mg ("in nature") and 0.79 mg of zinc (dehydrated). Therefore, it is not feasible to reach the zinc RDI just by consuming bananas, and there are no concerns about excess zinc from consuming the pseudo-fruit.

Molybdenum (Mo) is essential for human metabolism, with an RDI of 0.045 mg and no established maximum limit.[16] The bananas analyzed contained an average of 8.6 mg g^{-1} of molybdenum, consistent levels among green, ripe, "in nature" and dehydrated types. Consuming just one banana meets the daily molybdenum requirement; as for a medium-sized banana, we would have 0.688 mg.

TOXIC ELEMENTS

Antimony (Sb) is a valuable mineral to the human body in small daily doses, RDI between 0.5 and 1.0 mg. However, concentrations higher than 5 mg g^{-1} can cause adverse effects, such as headaches, respiratory problems, conjunctivitis, and ulcers. In even higher concentrations, antimony is classified as a carcinogenic agent, with a 50% lethal dose

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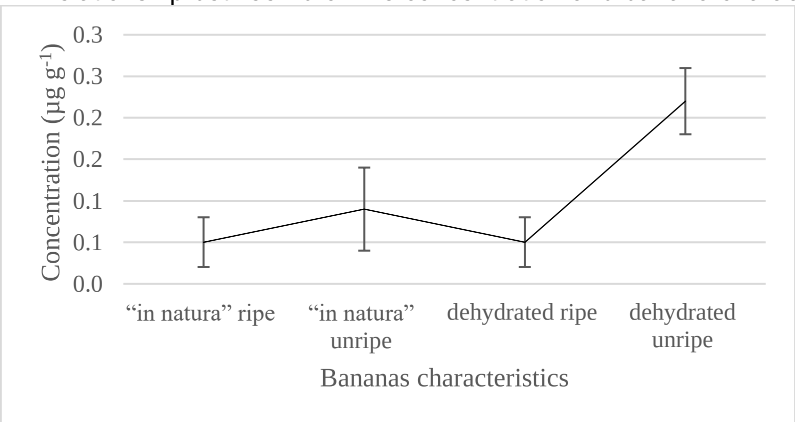
(LD50) of 7 mg g^{-1}.[17] Bananas had an average of 20.8 μg g^{-1}, and the values of this metal do not change with ripening and drying. If we consider an 80 g banana, each would have approximately 1.66 mg of antimony in its composition. Therefore, the consumption of just one banana is enough to reach the antimony RDI; the amount of antimony only becomes a concern if there is excessive consumption of bananas.

Cobalt (Co) is an essential mineral for the human body and has consequential insufficiency symptoms. However, daily intakes above 20 mg can cause adverse health effects, including heart, thyroid, and neurological problems and increased inflammation.[18] No maximum cobalt concentration established for foods was found. Although 23.44% of the samples in this study did not contain cobalt in their composition, the total average of this metal in all bananas groups was 102.4 μg g^{-1}, with no variations in cobalt concentration between unripe, ripe, "in nature," and dehydrated bananas. Considering an 80 g banana, each unit can contain approximately 8.192 mg of cobalt. Therefore, ingesting three units of the pseudo-fruit can reach the maximum recommended limit for cobalt, generating toxic effects on the body.

Bromine (Br) has no recognized essential biological function in humans; however, it can induce toxic effects in the body.[19] Daily doses ranging from 0.5 to 1 g can result in a condition called bromism, characterized by neurological deficiencies and other significant physiological disturbances.[20] In the bananas analyzed, bromine concentrations were 0.5±0.3 μg g^{-1} in fresh ripe bananas, 0.9±0.5 μg g^{-1} in fresh green bananas, 0.5±0.3 μg g^{-1} in dried ripe bananas, and 2.2±0.4 μg g^{-1} in dried green bananas (see Graph 2). Notably, bromine levels in dried green bananas were higher than others elements, which showed no significant difference. These data suggest that bromine levels decrease during the ripening process of bananas. Therefore, dehydrated ripe bananas pose less risk of bromism.

Graph 2 – Relationship between bromine concentration and banana characteristics



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The average manganese (Mn) content found was 49.1±22.8 μg g^{-1} in "in nature" ripe, 54.9±22.6 μg g^{-1} in "in nature" unripe, 62.9±13.7 μg g^{-1} in dehydrated ripe bananas, and 64.5±26 μg g^{-1} in dehydrated unripe bananas (Table 2). There is no significant difference between the types of samples because of the high standard deviation.

Manganese is an essential mineral for the human body; its RDI is 2.3 mg, and the daily limit of manganese per intake is 11 mg.[10] Based on the investigation's manganese concentration data, an 80 g ripe banana contains approximately 4 mg of manganese when fresh and 5 mg when dried. Consuming just one banana is sufficient to meet the RDI. However, consuming more than two bananas exceeds the maximum daily limit of manganese, which can adversely affect the organism. In a study titled "Manganese: An Invisible Risk" by Hernández et al.[21], it is reported that excessive manganese intake can lead to neurotoxicity and be linked to conditions like Parkinson's and Alzheimer's.

Iron (Fe) plays a critical role in numerous biological functions in the human body. An iron deficiency can significantly disrupt the production of hemoglobin, resulting in anemia and other related disorders.[22] According to ANVISA [11]and IOM [23], the recommended dietary intake (RDI) of iron for adults is 18 mg, with a daily intake limit of 45 mg. The average iron content found was 0.30±0.02 mg g^{-1} in "in nature" ripe, 0.29±0.03 mg g^{-1} in "in nature" unripe, 0.35±0.4 mg g^{-1} in dehydrated ripe bananas, and 0.15±0,03 mg g^{-1} in dehydrated unripe bananas (Table 2).

The data analysis unequivocally demonstrates that the iron concentration decreases during the drying process for unripe bananas and conversely increases during the drying process for ripe bananas. An 80 g banana contains approximately 12 mg (dehydrated unripe) and 28 mg (dehydrated ripe) of iron. Therefore, consuming a single banana would fulfill the iron RDI, while consuming two or more bananas would surpass the daily limit for iron intake.

Bismuth (Bi) is a metal that is considered non-toxic to humans. Despite being a heavy metal, there is no evidence of poisoning or adverse effects of Bi, as reported by Nordberg[24]. The average Bi concentration in bananas was 1.85 μg g^{-1}, with no variation observed between the groups sampled in the study. Consequently, there is no established limitation on banana consumption due to Bi content, nor is there a recommended daily dose since Bi does not perform a biological function as a nutrient in the human body.

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CONCLUSION

In the present study, it was possible to observe that the degree of maturity and the state of hydration of the banana can be related to the elemental concentrations in the silver banana. With the help of the experimental protocol established for the elemental analysis of bananas via EDXRF, empirical nutritional elemental data of the silver banana were obtained, which can add value to the banana product. Furthermore, in addition to the macro and micronutrients found in the pseudo-fruit, there are also impurities and heavy metals in its composition, making it sensible to be careful in the deliberate consumption of this food. For example, (i) consuming one silver banana is enough to reach the antimony RDI. A daily consumption limit of one silver banana, 'in nature" and dehydrated, was suggested based on the experimental data (considering the average mass, between 90 and 113 g, obtained in this work); and (ii) Consuming just one banana is sufficient to meet the manganese RDI. However, consuming more than two bananas exceeds the maximum daily limit of manganese, which can adversely affect the organism. To continue this research, it would be interesting to perform an elemental analysis of other banana species to compare with the present research and obtain the elemental concentrations in an even more complete and in-depth manner.

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