

Effect of the addition of *psyllium* (*Plantago Ovata* Forsk) on the total and bioaccessible concentration of the minerals sodium and potassium in frozen banana pulp

Efeito da adição de psyllium (*Plantago Ovata* Forsk) na concentração total e bioacessível dos minerais sódio e potássio na polpa de banana congelada

Efecto de la adición de psyllium (*Plantago Ovata* Forsk) sobre la concentración total y bioaccesible de los minerales sodio y potasio en la pulpa de banano congelada

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Abstract

Increased blood pressure is one of the main risk factors for cardiovascular disease. The World Health Organization (WHO) recommends that sodium intake should be moderate and potassium intake can be increased, as its intake is associated with a lower incidence of cardiovascular disease. Banana is a fruit rich in potassium and has large post-harvest losses due to its perishability. The production of frozen pulps is an alternative to reduce these losses. To add nutritional and functional benefits to the fruit pulp, it is possible to add soluble fiber, since its high intake is known to have a protective effect against cardiovascular disease and its intake by individuals does not meet the recommended minimum. There is evidence that psyllium dietary fiber contributes to lowering blood pressure, lowering cholesterol, lowering blood glucose and its incorporation into foods may offer health benefits such as preventing high blood pressure. Knowing that sodium and potassium intake is related to blood pressure, this study aimed to investigate the content of the minerals sodium and potassium in frozen banana pulp added with psyllium and to verify the concentrations of bioaccessibility in *in vitro* digestion. Our results showed that the addition of psyllium contributed to an increase in the content of the minerals potassium and sodium and that after the simulated digestions we verified that the final concentrations of the mineral potassium are in agreement with other results present in the literature, we also saw that despite increasing the sodium content, the final concentration of the dialysate (which would be absorbed by the human body) was 0.17%, being very low and ideal for preventing high blood pressure.

Keywords: Blood pressure; Cardiovascular disease; Dietary fiber; Chronic disease; Functional food.

Resumo

O aumento da pressão arterial é um dos principais fatores de risco para as doenças cardiovasculares. A Organização Mundial da Saúde (OMS) recomenda que o consumo de sódio deve ser moderado e o consumo de potássio pode ser

aumentado, pois sua ingestão está associada a uma menor incidência de doença cardiovascular. A banana é uma fruta rica em potássio e apresenta grandes perdas pós colheita devido sua perecibilidade. A produção de polpas congeladas é uma alternativa para reduzir essas perdas. Para agregar benefícios nutricionais e funcionais à polpa de frutas é possível adicionar fibras solúveis, visto que sua alta ingestão é conhecida por ter um efeito protetor contra doença cardiovascular e sua ingestão pelos indivíduos não atende ao mínimo recomendado. Há evidências que a fibra dietética *psyllium* contribui para a redução da pressão arterial, redução do colesterol, redução da glicemia e sua incorporação nos alimentos pode oferecer benefícios para a saúde como a prevenção da hipertensão arterial. Sabendo que o consumo de sódio e potássio tem relação com a pressão arterial este estudo teve por objetivo investigar o conteúdo dos minerais sódio e potássio em polpa congelada de banana adicionada de *psyllium* e verificar as concentrações das bioacessibilidades na digestão *in vitro*. Nossos resultados mostraram que a adição do *psyllium* contribuiu para um aumento no teor dos minerais potássio e sódio e que após as digestões simuladas verificamos que as concentrações finais do mineral potássio está de acordo com outros resultados presente na literatura, vimos também que apesar de aumentar o teor de sódio a concentração final do dialisado (o que seria absorvido pelo organismo humano) ficou em 0,17 %, sendo muito baixo e ideal para prevenir a hipertensão arterial.

Palavras-chave: Pressão arterial; Doença cardiovascular; Fibra alimentar; Doença crônica; Alimento funcional.

Resumen

El aumento de la presión arterial es uno de los principales factores de riesgo de enfermedad cardiovascular. La Organización Mundial de la Salud (OMS) recomienda que la ingesta de sodio sea moderada y se pueda incrementar la ingesta de potasio, ya que su ingesta se asocia con una menor incidencia de enfermedad cardiovascular. El banano es una fruta rica en potasio y tiene grandes pérdidas poscosecha debido a su perecibilidad. La producción de pulpas congeladas es una alternativa para reducir estas pérdidas. Para agregar beneficios nutricionales y funcionales a la pulpa de la fruta, es posible agregar fibra soluble, ya que se sabe que su alto aporte tiene un efecto protector contra las enfermedades cardiovasculares y su ingesta por parte de los individuos no alcanza el mínimo recomendado. Existe evidencia de que la fibra dietética de *psyllium* contribuye a reducir la presión arterial, reducir el colesterol, reducir la glucosa en sangre y su incorporación a los alimentos puede ofrecer beneficios para la salud, como prevenir la hipertensión arterial. Sabiendo que la ingesta de sodio y potasio está relacionada con la presión arterial, este estudio tuvo como objetivo investigar el contenido de los minerales sodio y potasio en la pulpa de banano congelada con *psyllium* y verificar las concentraciones de bioaccesibilidad en la digestión *in vitro*. Nuestros resultados mostraron que la adición de *psyllium* contribuyó a un aumento en el contenido de los minerales potasio y sodio y que luego de las digestiones simuladas comprobamos que las concentraciones finales del mineral potasio están de acuerdo con otros resultados presentes en la literatura, también Vio que a pesar de aumentar el contenido de sodio, la concentración final del dializado (que sería absorbido por el cuerpo humano) era del 0,17%, siendo muy baja e ideal para prevenir la hipertensión arterial.

Palabras clave: Presión arterial; Enfermedad cardiovascular; Fibra dietética; Enfermedad crónica; Comida funcional.

1. Introduction

Chronic Non-Communicable Diseases (NCDs) account for 72% of deaths worldwide (Thakur, Paika, & Singh, 2020) and among the main ones are cardiovascular diseases. The most common risk factors are increased blood pressure, increased blood glucose and increased cholesterol (Bennett et al., 2018).

High potassium intake is associated with a lower incidence of cardiovascular disease as it reduces blood pressure (Olde Engberink, van den Born, Peters-Sengers, & Vogt, 2020) and the World Health Organization (WHO) recommends for the adult population an intake of this mineral of at least 90 mmol / day (3,510 mg / day) (WHO, 2012).

According to the WHO (2003) the interest around the consumption of potassium grows due to its utility in public health and there is a need to find viable and economic actions that increase the intake of this mineral. In this way, the WHO recommends increasing the intake of potassium through food in order to reduce blood pressure and the risk of cardiovascular diseases.

The consumption of certain vegetables with a high potassium content is associated with a decrease in the risk of arterial hypertension and stroke. In societies where there was a reduction in the consumption of fruits and vegetables and the increase in the consumption of industrialized foods, it was observed that this change in eating habits caused an increase in sodium consumption (Na) that maintains a direct relationship with the increase in blood pressure(Weaver, 2013).

Sodium and potassium are important for the water balance in our body. Sodium retains fluids and potassium eliminates, leaving only the necessary amount, they are fundamental for muscle contraction and relate to blood pressure (Sun & Sun, 2018).

The WHO advises that sodium consumption for the adult population should be moderate (2g/ day), since its excessive consumption can cause hypertension and cardiovascular diseases. In Brazil its consumption exceeds the recommended (Orlando, Rebellato, Silva, Andrade, & Pallone, 2020).

According to Ezzati et al. (2018) to the consumption of fruits and vegetables may be among the potential factors for lowering blood pressure. Among the fruits, the banana (*Musa* spp.) is a source of potassium and deserves attention for being consumed worldwide due to its sensory acceptance (Sheng et al., 2010), however, it is a fruit that has great losses due to its high perishability (Md Nor & Ding, 2020). More than 48 million tons per year are lost worldwide (Molina-Ramírez, Cañas-Gutiérrez, Castro, Zuluaga, & Gañán, 2020).

An alternative to prevent waste is the production of frozen pulps, in addition to practical consumption. Its market is expanding and processing the fruits into frozen pulps adds profitable value to the product. The freezing process preserves the physical, nutritional and sensory properties of fruit pulp and its consumption has health benefits (Orqueda et al., 2021).

In addition to fruits, high dietary fiber intake is known to have a protective effect against cardiovascular disease, few individuals achieve the desired amount of fiber in their diets (Anderson et al., 2009).

To add nutritional and functional value to the frozen fruit pulp *psyllium* can be added, since it will increase the fiber content in the product without increasing caloric intake (Bernstein, Titgemeier, Kirkpatrick, Golubic, & Roizen, 2013).

Psyllium has benefits that are already well known in the literature due to its high content of soluble fiber contributing to add nutritional, functional and sensory value to foods. Among the functional properties are the reduction of blood glucose, reduction of cholesterol, relief of constipation, aid in weight loss by providing satiety among others (Franco et al., 2020). In Brazil, Brazilian Health Regulatory Agency (ANVISA) authorizes to inform on the label of products that present at least 3g of *psyllium* per serving the health claim that: “the consumption of the product allied to healthy habits decrease the absorption of fat” (Brazil, 1999).

There is evidence that *psyllium* contributes to the reduction of blood pressure (Bernstein et al., 2013) and the incorporation of it in diets can offer benefits for the prevention of arterial hypertension and as a consequence the reduction of the risk of cardiovascular disease. To date, there is no knowledge about the mechanism of action between fibers and their effect on blood pressure. There are some reports that have suggested that the benefit of fibers in lowering blood pressure would be related to their viscosity, which provides a slow absorption of some nutrients and this affects some metabolic indices, such as cholesterol, body weight and insulin resistance (Khan et al., 2018).

As far as we know, no study on the relationship in the consumption of soluble fibers and the regulation of pressure suggested that this benefit could also be related to the content of potassium and sodium in them. There are few studies on the composition of minerals in soluble fibers and no reports on the bioaccessibility of minerals K and Na in banana and *psyllium* have been found in the literature so far.

Although there are many studies on bioaccessibility, the literature is scarce regarding the bioaccessibility of minerals, studies on the bioaccessibility of polyphenols compounds are more common (Pereira et al., 2018).

Bioaccessibility refers to a fraction of a nutrient or a compound that is released from its matrix in the gastrointestinal tract, becoming available for intestinal absorption, whereas bioavailability is the amount of a nutrient or compound present in a food that the body can absorb in the intestine (Fernandez et al, 2009).

It is known that our body does not absorb the total concentration of nutrients from the foods that are ingested, due to this many bioaccessibility studies are under development so that one can have a better knowledge about the levels of elements (nutrients, phenolic compounds, metals) that is absorbed by the intestinal epithelium (Pereira et al., 2018).

This study aimed to investigate the effect of *psyllium* addition on physicochemical characteristics and verify the bioaccessibility of the minerals sodium and potassium in frozen banana pulp added *psyllium*.

2. Methodology

2.1 Chemicals and reagents

Pepsin, α -amylase, Pancreatin and bile salts were acquired from Sigma-Aldrich (São Paulo, Brazil). Hydrochloric acid (HCl) (37 % m/m), sulfuric acid (H₂SO₄), ethanol and methanol were purchased from Neon (São Paulo, Brazil). Phenolphthalein and sodium hydroxide were acquired from *Cequímica* (Fortaleza, CE).

2.2 Material

The banana (*Musa spp.*) of the cultivar "Prata" was acquired in the local market of the municipality of Iguatu/CE and was in the stage of maturation number 6 (Von Loesecke, 1950) and without treatment with ethylene.

The *psyllium* used in this research had 95% purity and contained about 80% dietary fiber, was purchased in a market in the municipality of Iguatu/CE. Citric acid (INS 330) and ascorbic acid (INS 300) were purchased from *Pantec Aditivos e Ingredientes, Brazil*.

2.3 Preparation of samples

The bananas were sanitized in running water and left in chlorinated solution at 200 ppm for 15 minutes, rinsed and subjected to natural drying for subsequent removal of the peels. The bananas were placed in a pulper (Braesi brand model DES-60/1) and then the other ingredients were added according to Table 1.

Table 1. Formulation of frozen banana pulp.

Sample	<i>Psyllium</i>	Banana	Citric acid	Ascorbic acid
Pulp 0%	0	99,6%	0,2%	0,2%
Pulp 3%	3%	96,6%	0,2%	0,2%

Source: Authors.

Added pulps of 3% *psyllium* and pulps without added *psyllium* were prepared. Ascorbic acid and citric acid were used to prevent enzymatic darkening and assist in product conservation (Brazil, 2013).

The pulps were stored at -8 °C and triplicate analyses took place the next day.

2.4 Measurement of pH

The pH was determined by direct reading, in potentiometer, calibrated with each use with buffer solutions of pH 4.0 and 7.0 according to IAL (2008).

2.5 Titratable total acidity (TTA)

The TTA was determined by the volumetric titration method with indicator following the IAL methodology (2008).

2.6 Color determination

The instrumental color determination of the samples was performed using colorimeter Chroma Meter CR-400 (Konica Minolta, Japan), using illuminant D65 and geometry 45/0, and the color values were expressed in the CIELAB system. The values of L* (Luminosity), a* (red-green component) and b* (yellow-blue component) were obtained directly from the colorimeter. L* ranges from 0 to 100, in which the value 0 indicates black (or dark color) and 100, white (light color). All measurements were carried out at a temperature of 20°C in the same light conditions (measuring area of 50 mm²) and replicated 6 times (Lawless; Heymann, 1998).

2.7 Determination of the minerals sodium (Na) and potassium (K)

Before spectrometric analysis, the samples were subjected to wet ash following the microwave digestion procedure in which 500 mg of sample was weighed directly into the digestion container. Nitric acid (HNO₃) at 65 % (v / v) (5 mL) and 30% hydrogen peroxide (H₂O₂) (v / v) (2 mL) were added to the samples, the vessels were covered and placed in the rotator body of the microwave oven (Milestone MLS 1200 Mega oven-Milestone, Bergamo, Italy) and the digestion program was carried out. The digestion conditions were: 1 min at 250 W (mild oxidation of organic matter); 1 min at 0 W (proceeding from reaction without adding energy to avoid temperature leaks and overpressures); 5 min at 250W (termination of mild oxidation of organic compounds); 5 min at 400 W and 5 min at 600 W (final termination of oxidation processes applying greater power). After cooling, the digested samples were transferred to volumetric vials and diluted to 50.0 mL using deionized water and then transferred to 50.0 mL polyethylene vials.

The macroelements sodium (Na) and potassium (K) were determined by inductively coupled Plasma atomic emission spectrometry (ICP-AES) in a thermo scan trace (Thermo Jarrell Ash Corporation, Franklin, USA); 588,995 nm for Na and 769,897 nm for K, using a standard technique (Jarrell Ash Corporation, 1995).

2.8 Simulated gastrointestinal digestion *in vitro* (bioaccessibility)

In this study, the salivary digestion simulation was not carried out, considering that the amylase enzyme acts in the breakdown of starch molecules, and in this study the pulps were prepared with ripe banana, with sugars being its main carbohydrate.

A simulated gastric fluid was used for digestion according to the procedures implemented by Moura and Canniatti-Brazaca (2006). The simulation of gastrointestinal digestion was performed with pepsin solubilized with HCl 0.1 mol L⁻¹ during the gastric phase and bile-Pancreatin salts, solubilized with NaHCO₃ 0.1 mol L⁻¹ in the intestinal phase.

Twenty grams of each sample of the pulps were weighed and added in 100 mL of HCl 0.01 mol L⁻¹, the pH was adjusted to 2 with HCl solution 2 mol L⁻¹ and added 3.2 mL of pepsin in the middle, and the sample was placed in a thermostatic bath with stirring at 37 °C for 2 hours to simulate the digestion of food in the stomach.

After adjusting the pH (0.5 mol L⁻¹ of NaOH up to pH 7.5) dialysis membranes (33 21 mm, molecular weight: 12,000-16,000, porosity: 25 Angstroms - InLab, Brazil) containing 0.1 mol L⁻¹ NaHCO₃ equivalent to titratable acidity were added to the gastric solution in a thermostatic water bath with stirring at 37 °C for 30 minutes. After this time, it was added 5.0 mL of Pancreatin solution and bile salts and stirred in a bath at 37 °C / 2 H. This step simulated digestion in the intestine.

At the end of this step, the contents of the inside of the membranes (dialysated) were collected and stored in amber glass tubes and the samples were stored at -8 °C until the moment of analysis.

For the correct quantification of minerals, it was performed simultaneously with the samples analytical whites containing the same reagents and conditions used in digesting them.

The dialysis samples were analyzed in triplicate by ICP OES for the determination of potassium (K) and sodium (Na). The bioavailable percentage was calculated by the concentration of each mineral released in the *in vitro* digestion process in relation to the total concentration of each element.

2.9 Data Analysis

The percentage (%) of bioaccessibility was calculated according to the equation: $BF (\%) = BE/TE \times 100$, onde BF é a porcentagem da fração bioacessível, BE é a fração do elemento bioacessível (mg 100 g⁻¹), dada pela concentração de um elemento encontrado nos extratos gástricos ou gastrointestinais, e TE é a concentração total do elemento (mg 100 g⁻¹) nas polpas.

The results of the total contents of the samples and the percentages of the bioaccessible fractions were presented as mean and standard deviation. Analysis of variance (ANOVA) and Tukey test ($p < 0.05$) were calculated to verify significant differences between the results. All statistical analyses were performed with the software Statistica v. 8.0 (StatSoft, 2007).

3. Results and Discussion

3.1 Physicochemical properties of the pulps

The effect of adding 3 % *psyllium* on physicochemical properties in frozen banana pulp is shown in Table 2.

Table 2. Physico-chemical results of frozen banana pulp.

Analyzes	Banana pulp	Banana pulp with <i>psyllium</i>
pH	4.21 ± 0.01 ^b	4.25 ± 0.02 ^a
ATT*	1.02 ± 0.01 ^a	1.02 ± 0.01 ^a
Color		
L*	71.5 ± 0.57 ^a	64.26 ± 0.19 ^b
a*	2.14 ± 0.53 ^b	4.8 ± 0.06 ^a
b*	21.66 ± 0.48 ^a	21.92 ± 0.19 ^a

* ATT-titratable total acidity in malic acid (%)

Different letters on the same line indicate that there was a significant difference by the Tukey test ($p < 0.05$).

Source: Authors.

The addition of *psyllium* was responsible for the significant increase in pH, but did not change for titratable acidity values. Table 2 showed the result of the concentration in malic acid, but we also verified the concentration of citric acid in the pulp and in both were found the equivalent of 1.1 g / 100 g of citric acid. The increase in pH probably must have been due to the fact that *psyllium* has a pH of 4.46 (Rao, Warriar, Gaikwad, & Shevate, 2016).

According to results found in the literature, banana is a fruit of low acidity, the values for pH and for total acidity is variable and depends on the degree of ripening post-harvest and the cultivar. It turns out that some studies have shown similar results for bananas (*Musa* spp.), reporting that the pH of bananas ranged from 4.3 to 5.5 (Etienne, Génard, Bancel, Benoit, & Bugaud (2013) and Bugaud, Maraval, Daribo, Leclerc, and Salmon (2016). The acidity in malic acid was investigated in the studies of Yap, Fernando, Brennan, Jayasena, and Coorey (2017) in bananas of the Cavendish cultivar and of Dotto, Matemu, and Ndakidemi (2019) the cultivar bananas of the Earth and the results showed values of 1.5 % to 2.3 % being similar to that found in this study (1.02 %).

It is noteworthy that in this study, citric and ascorbic acids were added to the pulp in order to avoid enzymatic darkening, being allowed by Resolution No. 8 of March 6, 2013 (Brazil, 2013). Even the concentration of the addition of acids being low (0.2 % each) may have affected on the total acidity and pH content.

According to normative instruction number 37, of October 1, 2018, the identity and quality standard for banana pulp must meet the minimum characteristics of pH 4.1 and total acidity expressed in citric acid 0.20 (g / 100 g) (Brazil, 2018), our pH and acidity results meet the required standard, being pH 4.2 and total acidity in citric acid 1.1 (g / 100 g).

As presented in Table 2, the results for the color measurement showed that the addition of 3 % *psyllium* significantly decreased the value of L^* (darker samples), this effect on darkening may be due to the color of *psyllium* being darker than the pulp of the banana. The darkening of the pulp with the addition of *psyllium* is related as the significant increase in a^* values, since it had no significant effect on b^* .

There are few studies with the addition of *psyllium* in food products, but it was verified that similar results were presented in studies Figueroa and Genovese (2019) in which *psyllium* fiber was used combined with other fibers in fruit jelly and showed a reduction in L^* values. In the studies of Raymundo, Fradinho, and Nunes (2014) the addition of *psyllium* in cookies also resulted in a darkening with reduction in luminosity values. Another study that showed similar results in the decrease of L^* values was with the use of *psyllium* in the production of a biodegradable film (Sukhija, Singh, & Riar, 2016).

Our results in the determination of color for banana pulp without the addition of *psyllium* were similar with the results of Yap et al. (2017) in banana puree from the Cavendish cultivar at the maturation stage 6, the authors performed bleaching followed by pH adjustment to 4 with citric acid (0.5 mol/L), the values were L^* 68.91, a^* -2.61 and b^* 24.6.

3.2 Determination of the minerals sodium (Na) and potassium (K)

The addition of *psyllium* in banana pulp resulted in a significant increase in the levels of minerals Na and K, as can be seen in Table 3.

Table 3. Average concentration for K and Na in banana pulp.

Sample	K (mg/g)	Na (mg/g)
Banana pulp with <i>psyllium</i>	405.33 ± 12.85 ^a	4.33 ± 0.15 ^a
Banana pulp	368 ± 20 ^b	1.36 ± 0.41 ^b

Different letters on the same line indicate that there was a significant difference by the Tukey test ($p < 0.05$).
Source: Authors.

In this study, we verified the concentration of the minerals potassium and sodium in *psyllium* and the results showed 861 mg / 100 g for potassium and 60 mg / 100 g for sodium. These results are in agreement with those found by Chong, Ball, McRae, and Packer (2019) who, when analyzing the *psyllium* mineral contents found 805 ± 2.3 (mg / 100 g) for potassium and 62.3 ± 2, 2 (mg / 100 g) for sodium.

It is possible to observe, as shown in Table 3, that there was a significant difference in the value of concentrations for K and Na in banana pulp with *psyllium*. The increase in the content of these minerals in the product confirms that *psyllium* is a fiber with high potassium content, as cited by Bukhsh, Malik, and Ahmad (2007); Guo, Cui, Wang, & Christopher Young (2008). It can be observed that the addition of 3 g of fiber provided a 10.14 % increase in potassium content and 218.38 % increase in sodium content in the pulp with the addition of *psyllium*.

Potassium is the most abundant mineral in bananas (Dotto et al., 2019; Etienne et al., 2013). When checking some studies with several banana cultivars, it was found that mineral concentrations are variable as to the type of cultivar and increase according to the stage of maturation (Yap et al., 2017).

In this work, the result for potassium in 100 g of banana pulp was similar to those found by Bugaud et al. (2013) for the cultivar “Yangambi” with potassium content in 338 mg. In the studies of Aquino, Carlos, Salomão, and Siqueira (2014) the banana of the cultivar “Prata” presented 317 mg and in the studies of Yap et al. (2017) with 343 mg in the cultivar “Cavendish”.

The banana has naturally low Na content and has not been found in the literature to date studies showing the concentration of this mineral in the pulp. Although the addition of *psyllium* increased the concentration of Na, it is still considered a low concentration, because according to the DRIs (Dietary Reference Intakes) the consumption of Na should be less than 2300 mg / day, and the concentration of this mineral in the added pulp of *psyllium* was 0.18 % compared to that recommended by DRI.

Some studies have related fiber consumption to cardioprotective functions and blood pressure control such as chia (Melo, Machado, & Oliveira, 2019; Ullah et al., 2016), flaxseed (Khalesi, Irwin, & Schubert, 2015; Ursoniu, Sahebkar, Andrica, Serban, & Banach, 2016), *psyllium* (Solà et al., 2010), but the biological mechanisms involved in lowering blood pressure are not fully understood in the literature.

Chia, flaxseed and *psyllium* were found to have good amounts of potassium and low sodium content. Kowaleski et al. (2020) found a total of 450 ± 70 mg / 100 g of potassium and 72 ± 13 mg / 100 g of sodium in chia, Deme, Haki, Retta, Woldegiorgis and Geleta (2017) found a total of 502 to 732 in linseed. mg / 100 g, the levels differed according to the cultivar. It is found in the Brazilian Table of Composition of Food (Brazilian Food Composition Table) - TACO that the potassium and sodium contents for 100 g of flaxseed (*Linum usitatissimum* L.) are 869 mg and 9 mg respectively (TACO, 2011).

After analyzing the data shown on the potassium and sodium contents for the aforementioned fibers, it was observed that the banana pulp added *psyllium* has potassium contents very similar to these studies, but the sodium contents were lower, being an ideal food source option for hypertensive people.

Several physiological mechanisms have been proposed for the effect of reducing blood pressure related to soluble fibers (Khan et al., 2018), however, to date, no relationship has been found in the literature between minerals in soluble fibers and blood pressure regulation. One hypothesis for the beneficial effect of these soluble fibers in relation to blood pressure control may be related to their high potassium content and low sodium content.

3.3 Bioaccessibility of minerals by *in vitro* digestion

The results of the concentrations of the minerals K and Na are shown in Table 4.

Table 4. Result of bioaccessibility (expressed as % of total concentration) of potassium and sodium in banana pulp

Minerals	Banana pulp	Banana pulp with <i>psyllium</i>
K	40.66 ± 1.15^a	39.33 ± 1.52^a
Na	92.33 ± 0.57^a	92.33 ± 0.57^a

Data are presented as mean \pm SD ($n = 3$).
Different letters on the same line indicate that there was a significant difference by the Tukey test ($p < 0.05$).
Source: Authors.

In this study, the white analytical was used to indicate the concentrations of minerals K and Na that could interfere with the results. For the bioaccessibility of Na, a high concentration of absorption was revealed. There are few studies on the bioaccessibility of sodium and potassium.

According to the literature, the absorption of nutrients will be hardly at 100%, the absorption of minerals can be affected by several inherent factors, such as the presence of mineral antinutrients (phytic acid, polyphenols and dietary fiber) and physical barriers (surrounding macronutrients and cell wall) (Rousseau, Kyomugasho, Celus, Hendrickx, & Grauwet, 2020).

As can be seen in Table 4, there was no significant difference in mineral concentrations resulting from *in vitro* digestion simulation between pulps with or without *psyllium* addition. The bioaccessibility of K was on average 40.66 % for the pulp with added *psyllium* and 39.33 % for the pulp without added *psyllium* and Na 92.33 % for both pulps, this means that when ingesting 100 g of frozen banana pulp added *psyllium* at the end of digestion possibly the organism will absorb 189.13 mg of K and 3.99 mg of Na and when ingesting the pulp without added *psyllium* the addition of *psyllium* the absorption content of K will be around 144.74 mg and stop at 1.25 mg, as can be verified in Table 2.

Beasley et al. (2020) When analyzing the nutrient intake of elderly women, they found that more than half of the participants were not meeting the consumption guidelines for potassium. The authors stressed the need to identify effective approaches to increase nutrient intake provided in the guidelines. As already reported in this work, adequate intake of K and Na are related to blood pressure control and insufficient intake of K increases the risk of cardiovascular disease (Adrogué & Madias, 2014).

Although K is part of the composition of almost all foods, the study on its bioaccessibility is rare, there are more published studies on the bioaccessibility of the minerals iron, zinc and copper. Similar result to this study was found Schulz et al. (2017) when evaluating the mineral contents of the juçara fruit, the authors verified that the K was the mineral with the highest quantities and the Na presented very low quantities. After simulating digestion *in vitro* they verified a bioaccessibility of potassium of 40% to 46% depending on the stage of maturation of the fruit. Bioaccessibility of Na has not been determined. According to the authors, the intake of 100 g of juçara fruit pulp corresponds to 4–5% of the daily needs for K, as directed by DRI.

Pereira et al. (2018), analyzed the content of minerals and their bioaccessibility in blackberry, raspberry, and blueberry. K was the most abundant mineral, but they could not determine the bioaccessibility content due to the reagents having large amounts of potassium in the formulation and the fraction released by the sample (hydrolysate) was very small.

According to the DRIs, potassium intake for people over the age of 19 should be 2600 mg / day for women and 3400 mg / day for men. Sodium intake guidance for people over the age of 19 should be at most 2300 mg / day to prevent the risk of chronic diseases (Institute of Medicine, 2019).

When analyzing the guidelines of the DRI for people over 19 years old, it can be observed that the frozen banana pulp added with *psyllium* will contribute to the intake of K in 7.27 % for women and 5.56 % for men, and the intake of Na in 0.17 %.

4. Conclusion

The results represent an important contribution to the area of nutrition, as it provides information on the approximate amounts of minerals that are absorbed in this product.

It was possible to verify that the addition of *psyllium* in the pulp presented a higher content of Mineral K. Our study suggests that the consumption of 100 g of the added frozen banana pulp of *psyllium* may contribute to the increase in K intake and presents health benefits as a lower risk of developing cardiovascular disease due to a decrease in the risk of hypertension

and stroke. This pulp meets the requirements to receive the health claim and can contribute to the reduction of LDL cholesterol.

More studies on the bioaccessibility of minerals, especially on K, in fruits and soluble fibers (*psyllium*, chia, flaxseed, oats) should be carried out, since there are few or no studies in this area.

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