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Mineral composition of fresh and dried peppers (*Piper nigrum* L.) from Côte d'Ivoire

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ABSTRACT

Pepper (*Piper nigrum*) is one of the most widely used spices in the food industries, in the pharmaceutical industries and in households. The objective of this work is to determine the minerals of fresh and dried peppers produced in Côte d'Ivoire. To this end, sampling was carried out on the basis of soil data from the Association of Pepper Producers of Côte d'Ivoire. The minerals (sodium, magnesium, phosphorus, potassium, calcium, iron and zinc) were determined using an inductively coupled plasma mass spectrometer (ICP-MS). The concentrations of sodium, magnesium, phosphorus, potassium, calcium, iron and zinc in the fresh and dried pepper samples were successively between 122 and 168 ppm; 2 and 2.95 ppm; 0.42 and 9.9 ppm; 12.02 and 20.66 ppm; 5.19 and 9.97 ppm; 4.70 and 14.89 ppm and 7.72 and 26.67 ppm. Secondly, minerals have several functions in the body and are necessary for the proper functioning of the body. They are present in our diet and are essential to our health. Finally, fresh and dried peppers contain sodium, magnesium, phosphorus, potassium, calcium, iron and zinc, which are essential for human nutrition.

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INTRODUCTION

Spices are the components of different parts of aromatic plants that come in many forms such as flowers (rose), flower buds (cloves), flower pistils (saffron), bark (cinnamon), roots (ginger, turmeric), seeds (nigella, tonka), stems (lemongrass) and fruits (chilli, vanilla, cumin, coriander and pepper) (Manandhar, 1995). Among the spices, peppers occupy a special place in the daily life of households in Africa. The pepper plant (*Piper nigrum* L.) is a perennial climbing plant in the Piperaceae family. It belongs to the genus Piper which has more than 1000 species (Ahmad *et al.,* 2012). It is generally grown at the beginning of the dry season after clearing the plantation of weeds (Chen and Tawan, 2020). Pepper production can extend over twenty years and the first seeds are observed from the third year onwards with a peak in production during the seventh year (Perrouin *et al.,* 2014). Worldwide, pepper production has dropped significantly in recent years. It fell from 633,000 to 497,000 tons successively in 2019 and 2021 (FAOSTAT, 2023). In addition, global demand for pepper was estimated at about 505,000 tons, a deficit of 8,000 tons, which is a loss for producers in 2021 (FAOSTAT, 2023). In Africa, the largest producers of pepper are Madagascar, Ghana and Ethiopia with successively 5,282.56 tons; 3,737.9 tons; 4,431.03 tons of pepper produced in 2021 (IPC, 2017; FAOSTAT, 2023). With a national production of 57.46 and 45.03 tons of pepper in 2020 and 2021 respectively, Côte d'Ivoire is classified as a country with low production (FAOSTAT, 2023). The different types of pepper produced there are mainly green pepper, white pepper, black pepper and red pepper.

Pepper is also rich in vitamins and minerals (calcium, magnesium, phosphorus, iron) and the benefits of its consumption are linked to its nutrient composition. For example, vitamin C participates in redox reactions, calcium participates in muscle contraction and magnesium participates in protein synthesis. The mineral composition of fresh and dried peppers (*Piper nigrum* L.) has been mentioned in the literature, but none of the reports has shown that there is a mineral valorization of peppers from Côte d'Ivoire. Thus, the present study was conducted with the aim of evaluating the mineral quality of pepper produced in Côte d'Ivoire.

The objective of this study was to examine the concentration of sodium, magnesium, phosphorus, potassium, calcium, iron and zinc in samples of fresh and dried pepper.

MATERIALS AND METHODS

The plant material consists mainly of fresh and dried pepper (*Piper nigrum*) (Fig. 1). They were purchased from producers in the localities of: Azaguié, Maféré, N'douci, Guibéroua, Danané, Niablé, Yakassé-Mé, Lopou, Assouba and Pk 103.



Fig. 1. Fresh pepper on the vine and destemmed dried pepper

Selection of sampling sites for fresh and dried peppers

An investigation previously conducted by FIRCA (FIRCA, 2020) survey of pepper producers in Côte d'Ivoire has identified 38 pepper plantations in production. Taking into account the geographical location and the distribution of the soils in Côte d'Ivoire, these plantations have been grouped into 10 different localities. They are mainly located in the areas of Azaguié, Maféré, N'douci, Guibéroua, Danané, Niablé, Yakassé-Mé, Lopou, Assouba and Pk 103**.**

Sampling of fresh and dried pepper

Samples of fresh and dried peppers were taken from producers in the ten (10) localities of Côte d'Ivoire. In these localities, five (05) samples with a mass of 1.5 kg for fresh pepper and 1.5 kg for dried pepper respectively were taken. After collection, the samples

of fresh peppers were packaged in coolers of about 10 kg containing dry ice. The samples were transported directly to the Laboratory of Industrial Processes, Synthesis, Environment and New Energies (LAPISEN) of the National Polytechnic Institute Houphouët Boigny (INP-HB).

Knowing that a sample consists of 1.5 kilograms, a total of forty-five (45) samples for fresh peppers and fifty (50) samples for dried peppers were the subject of this study. In the locality of Danané, samples of dried peppers were collected.

Determination of minerals in fresh and dried peppers

The determination of the minerals contained in a sample begins with the mineralization and preparation of the sample solutions. A quantity of 0.3 g of sample of fresh or dried pepper powder is weighed in a porcelain crucible and then put in the oven at 600 °C for 5 hours.

Digestion of samples of fresh and dried peppers in the sand bath

After cooling, 5 mL nitric acid (HNO_3, 1N) are added to the ash obtained and then brought to total evaporation on a sand bath. To the residue, 5 mL of hydrochloric acid (HCl, 1N) is added. It is then returned to the oven at 400 °C for 30 minutes. The final residue is recovered with 10 mL of hydrochloric acid and poured into a 50 mL flask. The crucible is rinsed three times with 10 mL of hydrochloric acid (HCl, 0.1N). The flask is topped up to 50 mL with deionized water, before the analysis of the minerals by ICP-MS (Poitevin, 2016).

Sample analysis by ICP-MS

Samples of fresh and dried pepper powder were analyzed using the technique of inductively coupled plasma mass spectrometry (Thermo Fisher Scientific Chromatography and Mass Spectrometry Hanna-Kunath-Strasse 11, Bremen, Germany).

The final solution (50 mL) is filtered using a 0.45 µm syringe filter in conical tubes. After filtration, 10 mL of solution is used for mineral analysis. The solution is conveyed by a peristaltic pump to a nebulizer which will transform it into an aerosol in a nebulization chamber.

The principle is based on the separation of elements in ionized form in a mass spectrometer according to the mass-to-charge ratio. Quantization is carried out using a detector placed after the quadrupole. The detector consists of a series of dynodes that transform the received ions into electrons that are amplified by the dynodes (essential components of the photomultiplier). It allows an extremely fast counting of masses in a sequential manner. Mineral concentrations are expressed according to relation 1:

$$Cm\ (ppm) = \frac{C \times Vt}{m} \quad (1)$$

Cm = concentration of the mineral in ppm
C = Concentration read on the device (ppm)
Vt = total volume (mL)
m = mass of the sample (g)

Statistical analysis

A probability threshold of less than or equal to 0.05 was chosen for the significance of all data exploitations. The data are expressed as an average plus or minus standard deviation. For the multiple comparison, the ANOVA test is used. The means are compared using the Duncan test. This test was carried out using the STATISTICA version 14 software.

RESULTS

Macro-elements of fresh and dried peppers

The mineralogical analysis of the 10 samples of fresh and dried pepper revealed the presence of five macronutrients (sodium, magnesium, calcium, phosphorus and potassium) presented in Table 1 and 2. Statistical analysis of the data shows a significant difference between the total sugar contents of fresh and dried peppers ($p < 0.05$). Statistical analysis of the data shows a significant difference ($p<0.05$) in all the macro element data for fresh and dried pepper. The lowest concentrations of sodium and magnesium were observed in fresh peppers from Yakassé-Mé (123.78 ± 0.01 ppm) and Niablé (2.2 ± 0.01 ppm),

respectively. The samples of fresh peppers with the highest sodium and magnesium contents were those taken from the locality of Assouba (168 ± 0.14 and 2.7 ± 0.02 ppm). Dried pepper samples from Assouba (164.51 ± 0.02 ppm) and Azaguié (2.97 ± 0.07 ppm) showed the highest sodium and magnesium contents, respectively, compared to those sampled at Yakassé-Mé (124.24 ± 0.05 ppm) for sodium levels and at Lopou (2.08 ± 0.02 ppm) for magnesium contents. The lowest calcium and phosphorus concentrations were collected successively in the localities of Azaguié (6.23 ± 0.32 ppm) and Lopou (2.14 ± 0.45 ppm). The highest calcium and phosphorus concentrations were observed in the fresh pepper samples collected in the locality of Yakassé-Mé (9.97 ± 0.1 ppm) and Assouba (9.9 ± 0.22 ppm). The highest calcium and phosphorus levels were found in dried pepper samples taken from the localities of PK 103 (6.17 ± 0.03 ppm) and Azaguié (3.13 ± 0.48 ppm). In contrast, dried pepper samples collected from the localities of Niablé (5.46 ± 0.23 ppm) and PK 103 (0.42 ± 0.45 ppm) revealed the lowest calcium and phosphorus contents, respectively. The dried pepper samples with the highest potassium levels were taken from Guibéroua (18.45 ± 0.28 ppm), PK 103 (18.36 ± 0.34 ppm) and Niablé (18.36 ± 0.73 ppm). Those with the lowest potassium concentrations came from Lopou (12.02 ± 0.45 ppm). Fresh pepper samples from PK 103 (20.66 ± 0.27 ppm) had the highest potassium levels compared to those sampled from Azaguié (12.32 ± 0.67 ppm) which showed the lowest potassium levels.

Table 1. Macro-elements of fresh pepper (ppm)

Localities	Na	Mg	Ca	P	K
Assouba	168 ± 0.14^{f}	2.7 ± 0.02^{c}	8.31 ± 0.03^{c}	9.9 ± 0.22^{e}	18.67 ± 0.46^{e}
Yakassé-Mé	123.78 ± 0.01^{b}	2 ± 0.05^{a}	9.97 ± 0.1^{e}	5.23 ± 0.47^{d}	15.56 ± 0.23^{d}
Maféré	140 ± 0.23^{e}	2.11 ± 0,02^{a}	8.02 ± 0.67^{c}	4.86 ± 0.07^{c}	14.7 ± 0.73^{c}
Azaguié	153 ± 0.32^{e}	2.3 ± 0.05^{b}	6.23 ± 0.32^{a}	5.88 ± 0.43^{d}	12.32 ± 0.67^{a}
N'douci	136 ± 0.04^{a}	2.7 ± 0.23^{c}	9.38 ± 0.25^{e}	5.36 ± 0.02^{d}	14.22 ± 0.31^{c}
Guibéroua	151 ± 0.13^{e}	2.4 ± 0.12^{b}	6.98 ± 0.22^{b}	3.72 ± 0.57^{b}	17.58 ± 0.56^{e}
PK 103	134.57 ± 0.05^{c}	2.4 ± 0.09^{b}	8.07 ± 0.36^{c}	4.21 ± 0.26^{c}	20.66 ± 0.27^{f}
Niablé	123 ± 0.32^{c}	2.2 ± 0.01^{a}	7.12 ± 0.58^{b}	3.23 ± 0.88^{b}	14.86 ± 0.75^{c}
Lopou	151±0.02^{e}	2.35 ± 0.05^{a}	8.78 ± 0.03^{d}	2.14 ± 0.45^{a}	13.57 ± 0.02^{b}

The values in the same column with the same letter are not significantly different from each other based on Duncan's 5% threshold multiple comparison test. Values are expressed as mean ± standard deviation (n = 3 determinations); Na: sodium; Mg: magnesium; Ca: calcium; P: phosphorus; K: potassium

Table 2. Macro-elements of dried pepper (ppm)

Localities	Na	Mg	Ca	P	K
Assouba	164.51 ± 0.02^{f}	2.73 ± 0.05^{c}	5.36 ± 0.31^{a}	2.45 ± 0.23^{d}	12.88 ± 0.51^{b}
Yakassé-Mé	124.24 ± 0.05^{b}	2.1 ± 0.08^{a}	5.21 ± 0.67^{a}	1.06 ± 0.37^{b}	13.57 ± 0.24^{c}
Maféré	148.08 ± 0.1^{e}	2.04 ± 0.45^{a}	5.79 ± 0.06^{b}	1.26 ± 0.43^{b}	13.62 ± 0.12^{c}
Azaguié	156.71 ± 0.03^{e}	2.97 ± 0.07^{d}	6.1 ± 0.47^{c}	3.13 ± 0.48^{e}	12.87 ± 0.61^{b}
N'douci	122.91 ± 0.22^{a}	2.87 ± 0.1^{c}	6.09 ± 0.57^{c}	1.07 ± 0.38^{b}	12.61 ± 0.04^{b}
Guibéroua	153.12 ± 0.05^{e}	2.95 ± 0.02^{d}	5.19 ± 0.22^{a}	2.47 ± 0.12^{d}	18.45 ± 0.28^{e}
PK 103	132.57 ± 0.04^{c}	2.47 ± 0.02^{b}	6.17 ± 0.03^{d}	0.42 ± 0.45^{a}	18.36 ± 0.34^{e}
Niablé	129.61 ± 0.08^{c}	2.34 ± 0.01^{b}	5.46 ± 0.23^{a}	1.86 ± 0.13^{c}	18.36 ± 0.73^{e}
Lopou	152.83 ± 0.08^{e}	2.08 ± 0.02^{a}	6.07 ± 0.38^{c}	1.71 ± 0.84^{c}	12.02 ± 0.45^{a}
Danané	138.08 ± 0.12^{d}	2.62 ± 0.5^{c}	5.98 ± 0.27^{b}	0.54 ± 0.55^{a}	17.2 ± 0.34^{d}

The values of the same line with the same letter are not significantly different from each other according to the Duncan multiple comparison test at the 5% level. The values are expressed as mean ± standard deviation (n = 3 determinations); Na: sodium; Mg: magnesium; Ca: calcium; P: phosphorus; K: potassium

Fe, Zn contents of fresh and dried peppers

The results of the micronutrient contents of the different samples of fresh and dried peppers are mentioned in Table 3 and 4. The statistical analysis of the data shows a significant difference ($p<0.05$) in all the data of the microelements of fresh and dried peppers. The samples

of fresh peppers with the highest iron contents were taken from the localities of Yakassé-Mé (13.59 ± 0.49 ppm) and Lopou (13.51 ± 0.05 ppm) and PK 103 (14.89 ± 0.35 ppm). Those with the lowest iron concentrations came from N'douci (4.7 ± 0.25 ppm) and Guibéroua (6.34 ± 0.01 ppm). Dried pepper samples from Pk 103 (14.16 ± 0.92 ppm) contained the highest iron levels compared to those sampled from N'douci (5.46 ± 0.03 ppm) and Guibéroua (6.45 ± 0.03 ppm) which had the lowest iron contents.

Table 3. Iron content of fresh and dried pepper (in ppm)

Localities	Fresh pepper	Dried pepper
Maféré	10.06 ± 0.04^{bc}	10.52 ± 0.01^{abc}
Assouba	10.77 ± 0.25^{bc}	13.86 ± 0.09^{bcd}
Guibéroua	6.34 ± 0.01^{b}	6.45 ± 0.03^{ab}
Azaguié	14.76 ± 0.02^{cde}	14.62 ± 0.08^{e}
Pk 103	14.89 ± 0.35^{e}	14.16 ± 0.92^{bcd}
Yakassé-Mé	13.59 ± 0.43^{cde}	11.11 ± 0.85^{abc}
Lopou	13.51 ± 0.05^{cde}	13.53 ± 0.02^{bcd}
Niablé	11.85 ± 0.06^{bcd}	11.43 ± 0.13^{abc}
N'douci	4.7 ± 0.25^{a}	5.46 ± 0.03^{a}
Danané	-	10.66 ± 0.82^{abc}

Values in the same column with the same letter are not significantly different from each other based on Duncan's 5% threshold multiple comparison test. Values are expressed as a mean ± standard deviation (n = 3 determinations)

Table 4. Zinc content of fresh and dried pepper (in ppm)

Localities	Fresh pepper	Dried pepper
Maféré	19.87 ± 0.35^{cd}	20.38 ± 0.13^{cd}
Assouba	25.64 ± 0.67^{cde}	26.66 ± 0.07^{d}
Guibéroua	25.88 ± 0.12^{e}	26.67 ± 0.34^{d}
Azaguié	11.56 ± 0.03^{b}	11.12 ± 0.02^{b}
PK 103	14.72 ± 0.45^{bcd}	14.33 ± 0.23^{bcd}
Yakassé-Mé	12.38 ± 0.67^{b}	14.12 ± 0.59^{bcd}
Lopou	12.55 ± 0.53^{bc}	20.38 ± 0.03^{cd}
Niablé	7.72 ± 0.34^{a}	7.84 ± 0.09^{a}
N'douci	12.56 ± 0.55^{bc}	10.97 ± 0.02^{b}
Danané	-	12.55 ± 0.73^{bc}

Values in the same column with the same letter are not significantly different from each other based on Duncan's 5% threshold multiple comparison test. Values are expressed as a mean ± standard deviation (n = 3 determinations)

The highest zinc concentrations in the fresh pepper samples were observed in the fresh pepper samples collected in the localities of Assouba (25.64 ± 0.67 ppm) and Guibéroua (25.88 ± 0.12 ppm), while the lowest zinc concentrations were observed in the fresh pepper samples collected in the locality of Niablé (7.72 ± 0.34 ppm). The dried pepper samples from Guibéroua (26.67 ± 0.34 ppm) contained the highest zinc concentrations compared to those collected in Niablé (7.84 ± 0.09 ppm), which showed the lowest zinc concentrations.

DISCUSSION

Sodium plays a very important physiological role in maintaining extracellular fluid balance, regulating osmotic pressure, and regulating homeostasis. The sodium contents are close to those of Abukawsar *et al.* (2018) in India, which obtained sodium levels ranging from 137.18 to 154.96 ppm for fresh and dried pepper from the native region and from 142.5 to 162.06 ppm for fresh and dried pepper from the Kerala region. On the other hand, the sodium concentrations of fresh and dried pepper analysed are lower than those obtained by Fathivand *et al.* (2017) who found sodium levels between 153 and 2849 ppm in spices consumed in Tehran (Iran). In addition, the sodium levels of fresh and dried pepper taken from the different localities are higher than those obtained by Özcan and Akbulut (2008). These authors obtained

concentrations ranging from 1102.62 to 20912.33 ppm in 31 types of aromatic and medicinal plants collected in the southern region of Turkey. On the other hand, the sodium content of the peppers studied is higher than those of Zaki *et al.* (2018), which obtained sodium levels of 34.04 to 65.64 ppm in paprika produced by a semi-industrial process from Niora (*Capsicum annum*) grown in three regions of Morocco. Overall, the sodium levels of fresh and dried pepper are higher than the United States Department of Agriculture (USDA, 2017).

Magnesium plays an important role in cellular and physiological functions. These functions include enzymatic reactions in cells, protein synthesis, and cellular energy production. It also plays a role in the formation of bones and teeth. The magnesium contents of the various fresh and dried pepper samples analyzed are close to those of Abukawsar *et al.* (2018) in India who found magnesium concentrations of 2.07 to 2.34 ppm for fresh and dried pepper from the native region and 2.05 to 2.33 ppm for fresh and dried pepper from the Kerala region. Similarly, magnesium levels are similar to those seen in carum (2.55 ppm) and fenugreek (2.31 ppm) (Gupta *et al.,* 2003). However, magnesium concentrations in fresh and dried pepper samples are higher than those obtained by Gupta *et al.* (2003) which obtained magnesium levels of 1.79 and 1.8 ppm in black pepper. In addition, magnesium levels are higher than those of Weil (2018) in Madagascar, which found a magnesium content of 0.29 ppm in wild pepper. In general, the recommended daily doses of magnesium vary between 80 and 480 mg for the proper physiological functioning of the human body (FAO, 1998).

Overall, magnesium levels in fresh and dried pepper are lower than the United States Department of Agriculture (USDA, 2017).

Phosphorus levels are consistent with those of Partelli (2009) in Brazil, which obtained a concentration of 2.10 and 2.18 ppm successively in the leaves and peppercorns. On the other hand, the phosphorus contents of the *Piper nigrum* (1.45 ppm) and *Piper guinea* (0.94 ppm) reported by Ameh *et al.* (2016) are lower than the phosphorus levels of the samples of fresh and dried pepper taken from our various study sites. Similarly, the phosphorus concentrations of fresh and dried pepper are lower than those of Weil (2018) in Madagascar, which obtained a content of 0.24 ppm in wild pepper (*Piper guinea*). Phosphorus is an essential mineral that helps form bone and is a component of cell membranes, nucleic acids, and adenosine triphosphate (ATP), which supports cellular energy transfer (Wagner, 2024). It plays an important and essential role in the human body, as it helps convert food into energy, aids in growth, and various repair processes in the body. It is involved in the formation of bones, teeth, nucleic acids, and phosphoproteins (Lesniewicz *et al.,* 2006). Phosphorus also plays an important role in the metabolism of fats and starch, reduces pain caused by arthritis, and normalizes heart rate and kidney function. So consuming pepper can help meet the needs (Gupta *et al.,* 2003).

The potassium levels of the fresh and dried pepper samples analyzed are higher than that of Weil (2018) which found a content of 2.35 ppm in wild pepper from Madagascar. Similarly, our values are higher than those of Partelli (2009) which obtained concentrations of 12.2 to 14.2 ppm in peppercorns and leaves in Brazil. Our results are similar to those of Abukawsar *et al.* (2018) which had potassium levels of 12.36 to 13.96 ppm in fresh and dried pepper from the native region and 18.26 to 20.77 ppm in fresh and dried pepper from the Kerala region of India. In contrast, the potassium concentrations in fresh and dried pepper are lower than those of Ameh *et al.* (2016) in Nigeria, which found potassium levels of 58.60 ppm in dried pepper (*Piper nigrum*) and 33.70 ppm in wild pepper (*Piper guinea*). Potassium plays a major role in the functioning of the body. It has a protective effect against cardiovascular disease by reducing blood pressure and preventing the appearance of vascular kidney damage (Weaver, 2013). It also contributes to the reduction of urinary calcium excretion, thus causing a positive calcium balance. In addition, it reduces the risk of developing

type II diabetes by reducing glucose intolerance, and has a beneficial effect on bone health (Zillich *et al.,* 2006). Overall, the potassium levels of fresh and dried pepper are higher than the United States Department of Agriculture (USDA, 2017).

The results are similar to those of Abukawsar *et al.* (2018), which obtained calcium levels of 8.17 to 9.23 ppm in fresh and dried pepper from the indigenous region of India and 5.52 to 6.28 ppm in fresh and dried pepper from the Kerala region. Similarly, the calcium levels of the fresh and dried peppers analysed are similar to those of Partelli (2009) in Brazil, which found a calcium content of 7.8 ppm in peppercorns. Second, the calcium concentrations in the fresh and dried pepper samples are close to that of Ameh *et al.* (2016) in Nigeria, which obtained a value of 6,44 ppm in dried pepper (*Piper nigrum*). On the other hand, the values are higher than that of Weil (2018) in Madagascar, which had a content of 0.43 ppm in wild pepper (*Piper guinea*). Calcium is an important mineral for the body. It plays a crucial role in the constitution of bones and teeth and actively participates in the regulation of nervous, muscular and hormonal functions (Ferreira *et al.,* 2013). A study on pepper consumption reveals that 10 g of spice can be ingested daily by a human being. This suggests that pepper can contribute between 6.2 and 159 mg of calcium intake and therefore represents between 0.7 and 17.7% of the recommended daily requirement (FAO, 1998). Overall, calcium levels in fresh and dried pepper are lower than the United States Department of Agriculture (USDA, 2017).

Thus, all the variations in the content of different minerals in fresh and dried peppers from one region to another and from one part to another of the same pepper could be explained by the state of maturity of the peppers and the conditions of the root system. For, according to Leterme *et al.* (2006), several factors, including variety, maturity, soil type, soil condition and irrigation regime, can lead to variation in mineral and trace element levels in different types of fruit as well as in different parts of peppercorns. In addition, other factors such as fruiting position and leaf area of forest canopy can also influence the mineral content and quality of peppercorns (Volz *et al.,* 1994). Macronutrient deficiencies can lead to a variety of health problems, such as anemia and muscle weakness. Lack of macronutrients in the blood can be a cause of many chronic diseases. Hormonal changes resulting from macronutrient deficiency lead to consequences that can lead to weight gain, obesity, and an increased risk of cancer in the future. It is important to maintain a balanced diet to ensure adequate intake of macronutrients.

Iron contents are lower than those of Abukawsar *et al.* (2018) which obtained iron levels ranging from 122.46 to 138.36 ppm in fresh and dried pepper from the indigenous region of India and from 302.53 to 344.07 ppm in fresh and dried pepper from the Kerala region. In addition, the iron levels of the fresh and dried pepper samples analyzed are lower than those of Weil (2018) in Madagascar, which obtained a concentration of 35.35 ppm for wild pepper (*Piper guinea*). Similarly, the iron content obtained by Zaki *et al.* (2018) in the Tadla region of Morocco (33.02 ppm) are higher than those of the fresh and dried pepper samples analyzed. Iron is a component of hemoglobin in red blood cells, which carries oxygen from the lungs to body tissues. Iron also supports enzyme function and participates in electron transfer in the mitochondrial respiratory chain (Koleini *et al.*, 2021). Dietary iron intake is between 7 and 30 mg/day, which allows us to suggest that fresh and dried peppers in general have sufficient content to cover dietary requirements (FAO, 1998). Overall, the protein content of fresh and dried pepper is higher than the United States Department of Agriculture (USDA, 2017).

Zinc levels in fresh and dried pepper samples are lower than those of Iwegbue *et al.* (2011) in Nigeria, which obtained zinc levels ranging from 30 to 44.02 ppm in spices (*Abelmoschus esculentus, Amarathus spinosis, Cucumis sativa, Talinium triangulare, Daucus carrota, Phaseolus vulgaris, Vernonia amygdalina, Piper nigrum, Lycopersicon*

esculentum, Telfaria occidentalis, Cochorus olitorius, Allium cepa, Brassica oleraca Tephrosia densiflora, Capsicum annum, Citrullus vulgaris, Tetrapleura tetraptera, Anisophylea spp., *Piper guineensis, Mynstica fragrans, Aframomum melegueta and Allium sativum*). In addition, our results are weaker than those of Nkuba and Mohammed. (2017) in Tanzania, which obtained a concentration of zinc in 20 different types of spices and medicinal plants. On the other hand, the zinc contents of the samples of fresh and dried peppers are higher than those of Zaki *et al.* (2018) in Morocco, which showed zinc levels of 1.33 ppm in pepper from the El Kalâa region of the Sraghra and 1.97 and 2.03 ppm in paprika from the El Gharb and Tadla region. Zinc can prevent cardiomyopathy and stunted growth. Its zinc deficiency can lead to a lack of appetite and a weakened immune system. Zinc deficiency is thought to cause diarrhea, delayed sexual maturation, and lesions in the eyes and skin (Imoberdorf *et al.,* 2010).

In humans, correcting iron deficiencies and optimizing micronutrient levels in humans depends on several factors, including current dietary intake, dietary habits, and the nutrient content of the foods consumed (Nieder *et al.,* 2018).

CONCLUSION

The samples of fresh and dried peppers as a whole showed a richness in minerals both qualitatively and quantitatively. Minerals such as sodium, magnesium, calcium, phosphorus and potassium were mostly quantified in the samples of fresh and dried peppers. There is a clear predominance of sodium in the various samples of fresh and dried peppers studied with a peak of 168 ppm. Apart from the above-mentioned minerals, the samples of fresh and dried peppers also contain microelements such as iron and zinc in terms of quantities.

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