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Research Article

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Analysis of Minerals in Watermelon (*Citrullus lanatus*)

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ABSTRACT

The high consumption of watermelon (Citrullus lanatus) in Senegal has raised questions about the quality of this fruit and its health consequences. Watermelon bought from three different localities in the Dakar peninsula (Rufisque, Castors, and Tilène) were studied. Their nitrates, chlorides, and fluorides ions contents were assayed by specific electrodes, while the analyses of sodium ions were done by flame photometry. Nitrates concentrations were found to be about 210 mg/l, 250 mg/l, and 170 mg/l respectively for samples from Rufisque, Castors, and Tilène. Analyses of fluorides showed concentrations of 6 mg/l, 8 mg/l, and 7 mg/l respectively for the samples from Rufisque, Castors, and Tilène. The results for chlorides revealed concentrations of 100 mg/l, 40 mg/l, and 120 mg/l respectively for samples from the same three localities. And finally, sodium concentrations obtained were roughly similar for all three localities, and were respectively 27 mg/l, 26 mg/l, and 26 mg/l.

Keywords: Watermelon; Minerals; Senegal

INTRODUCTION

A healthy diet is essential to human life. Many studies have shown the contribution of foods, including fruits and vegetables, to certain pathologies. Indeed, oxidative stress is increasingly implicated in the onset and progression of certain diseases like cancer, cardiovascular, neurodegenerative and aging. And according to some studies [9], dietary intake of antioxidants is nowadays insufficient because of several factors: the decrease in antioxidant levels with intensive agriculture, increased pollution of food supply, city life being a source of stress, environmental pollution, unbalanced diet and passive smoking, etc. This explains the steadily increasing interest on natural products and good nutritional quality.

Watermelon or *citrullus lanatus*, a cucurbitaceae, is a fruit with many virtues due to its citrulline content, a precursor to arginine, its lycopene content, and other trace elements, etc.. Studies have highlighted its potential anti-diabetic properties. Watermelon's action on atherosclerosis, its anti-inflammatory, antioxidants, anti-ulcer, neural and hepatoprotective effects have all been demonstrated [1-40].

In Senegal, with a production of 240,000 tons in 2010, the watermelon is very much consumed locally despite exports to France and Spain. It is thus a fruit with a high added value [12].

As part of this study, locally produced watermelon's contents in chlorides, fluorides, and nitrates were measured using the method of specific electrodes and its sodium ions content measured by flame photometry. Indeed, these minerals are essential to the enzymatic and hormonal functioning of the body, the structure of bones and teeth, maintaining heartbeat, muscle contraction, neuronal conductivity and acid-base balance. However, relatively high levels can be source of toxicity [4,38]. Thus, this study aims to perform quality control on the content of these minerals in watermelon, given its strong local consumption.

MATERIALS AND METHODOLOGY

Sampling

The study was conducted in Dakar (Senegal) from November 2012 to January 2013. The Dakar region covers an area of 550 km^2, or 0.28% of national territory. It is the political, economic and cultural capital of Senegal, with 80% of commercial and cultural enterprises and nearly a quarter of the total population.

Samples for this study consisted of watermelons bought from markets located in three different localities in the Dakar area: Rufisque, Castors, and Tilène. Watermelons were bought at random and their average weight ranged from 3 to 4 kg.

Apparatus and reagents

A CONSORT pH meter was used for the analysis of different ions, with an ORION model 93-07 electrode for nitrate ions, an INGOLD model 15 213 300 electrode (with $AgCl/Ag_2S$ pellets) for chloride ions, an ORION 94-09, 96-09 electrode (with lanthanum fluoride crystals) for fluoride ions, and a reference electrode INGOLD model 373 90 WTE. ISE. S7 (with Ag/AgCl). Finally, the analysis of sodium ions was performed with an ELVI 660 flame photometer. All reagents used met purity requirements for analysis.

Methods

Extraction:

Each watermelon sample is washed, rinsed with distilled water and cut using a stainless steel knife. Then, 400 g of seedless flesh are removed and reduced to a homogeneous slurry using a blender. A juice is then obtained after filtration in vacuum and each analysis is performed using 25 ml of juice from every sample.

Analysis of ions by electrochemical method:

This method consisted of measuring the potential using a system of electrodes and a potentiometer. The potential at the working electrode was measured directly relative to a reference electrode [35]. After this measurement, the concentration of the sample ion was determined using a calibration curve established with known concentrations of the measured ion. The addition of a TISAB (Total Ionic Strength Adjustment Buffer) buffer solution allowed to increase the ionic strength and maintain the stability of the solution for analysis [35]. Each one of the analysis uses a specific TISAB solution.

Determination of nitrate ions:

The stock solution was obtained from potassium nitrate. Its concentration in nitrates, 0.885 g/l, yielded daughter solutions of concentrations 0.443 g/l, 0.222 g/l, 0.088 g/l, and 0.044g/l.

For the determination of nitrates, the reference electrode was filled with a saturated solution of potassium chloride, and the TISAB solution was an ammonium sulfate of 2M.

Determination of chloride ions:

The stock solution was composed of sodium chloride at a concentration of 0.76 g/l from which daughter solutions of concentration of 0.38 g/l, 0.19 g/l, 0.076 g/l, and 0.038 g/l were extracted. The determination of chloride ions required as a reference, a potassium nitrate solution of 1M. The TISAB solution was a sodium nitrate of 425 g/l concentration.

Determination of fluoride ions:

The stock solution was made of sodium fluoride at a concentration of 0.1 g/l, and daughter solutions of concentrations 0.050 g/l, 0.25 g/l, 0.010 g/l, and 0.005 g/l were produced. The filling solution of the reference electrode for the determination of the fluoride ions is a potassium chloride solution at a concentration of 100 g/l. The TISAB solution was made of an equal mixture of trisodium citrate at a concentration of 58.8 g/l and a sodium chloride solution at a concentration of 58.5 g/l. A citric acid solution of concentration 12.5 g/l was used to adjust the solution prepared at a pH of 5.5.

Joint protocol for the analysis of nitrate, chlorides, and fluorides ions:

In a 150 ml beaker was introduced 25 ml of the watermelon juice sample and 0.5 ml of the TISAB solution. The specific electrode is carefully washed with distilled water, dried with filter paper and then introduced into the solution to be analyzed, as well as the reference electrode filled with the saturated solution specific to the ion being analyzed. Reading of the potential was made after 5 min including 2 min of very gentle magnetic stirring followed by 3 min of rest. After each reading, the electrodes were again thoroughly rinsed with distilled water and then dried with filter paper. This procedure was performed for each solution of the calibration range and for each sample. Each solution was measured three times and the mean and standard deviation of the measurements were calculated.

Determination of the sodium by flame photometry:

The stock solution was made of sodium chloride with a concentration of 0.5 g/l, and daughter solutions with sodium ion concentrations of 0.25 g/l, 0.025 g/l, 0.010 g/l, and 0.005 g/l were prepared. The flame photometer was calibrated so that the intensity of the current was between 0 mA and 95 mA. The results obtained allowed to plot calibration curves used to determine concentrations of samples to be analyzed.

RESULTS AND DISCUSSION

Results of analysis by specific electrodes

The various concentrations were determined using the equation $Y = A + BX$ given by the calibration curve, where Y is the potential in mV, A is the Y intercept, B is the slope of the line, and X is the logarithm of the concentration of the element to be analyzed. This study was performed in parallel to another study involving the analysis of minerals in filtered and purified water [36], and therefore both analyses shared the same calibration solutions.

Determination of nitrate ions

Table 1: Concentrations (g/l) of nitrates in calibration solutions

Calibration Solution	Stock	1	2	3	4	Distilled water
Mean Potential (mV)	68	82.87	98	116.33	128.67	164.33
Concentration (g/l)	0.916	0.445	0.209	0.085	0.046	0.008

Table 2: Concentrations (g/l) of nitrates in samples

Sample	Rufisque	Castors	Tilène
Mean Potential (mV)	98.33	94.67	102.67
Concentration (g/l)	0.21	0.25	0.17

Determination of fluoride ions

Table 3: Concentrations (g/l) of fluoride ions in calibration solutions

Calibration solution	Stock	1	2	3	4	Distilled water
Mean Potential (mV)	23.3	40.9	58.4	81.5	99.17	216.37
Concentration (g/l)	10	4.99	2.5	1	0.05	0.005

Table 4: Concentrations (g/l) of fluorides in samples

Sample	Rufisque	Castors	Tilène
Mean Potential (mV)	210.53	203.83	207.8
Concentration (g/l)	0.006	0.008	0.007

Determination of chloride ions

Table 5: Concentrations (g/l) of chloride ions in calibration solutions

Calibration solution	Stock	1	2	3	4	Distilled water
Mean Potential (mV)	71.4	89	105.7	128.8	145.8	226.4
Concentration (g/l)	0.74	0.37	0.185	0.073	0.037	0.001

Table 6: Concentrations (g/l) of chlorides in samples

Sample	Rufisque	Castors	Tilène
Mean Potential (mV)	121.47	146.67	115.73
Concentration (g/l)	0.1	0.04	0.12

Result of the analysis of sodium by flame photometry

Table 7: Concentrations (g/l) of sodium ions in calibration solutions

Calibration solution	Stock	1	2	3	4	Distilled water
Mean Current (mA)	94	73.7	56.7	37.7	27	0
Concentration (g/l)	0.58	0.23	0.11	0.05	0	0.01

Table 8: Concentrations (g/l) of sodium in samples

Sample	Rufisque	Castors	Tilène
Mean Current (mA)	26	24.5	24.5
Concentration (g/l)	0.027	0.026	0.026

DISCUSSION

The results obtained showed nitrates concentrations of 210 mg/l, 250 mg/l, and 170 mg/l respectively for samples from Rufisque, Castors, and Tilène. The "Joint FAO/WHO Expert Committee on Food Additives" recommends to not exceed for an adult, an acceptable daily intake (ADI) of 3.65 mg/kg/day of nitrates. Thus, for a 70 kg adult, this corresponds to 255 mg of nitrates per day. WHO estimates the daily dose ingested by a European adult to be between 120 and 300 mg. The ADI set by the US Agency for Environmental Protection (EPA) is about 7.1 mg/kg/day or 497 mg for an adult of 70 kg. The ADI for fluorides is 0.05 mg/kg/day, which corresponds to 3.5 mg maximum daily intake for an adult.

We estimate a seasonal daily consumption of watermelon for an average Senegalese adult of 70 kg to be about 400 mg of fruit corresponding to about 250 ml of extracted juice. Therefore, the studied samples can provide by themselves up to a quarter (52.5 mg, 62.5 mg, 42.5 mg) of the daily nitrates intake recommended by WHO and EPA for the average Senegalese adult. It should however be noted that the ADIs take into account all the nitrates provided through the diet and are of various origins: drinking water, vegetables, breads, dairy products, and meats. Some food, especially vegetables, fruits and salted meat (and to a lesser extent fish and dairy products) may contain a high dose of nitrates. Indeed, the nitrates content of plants is influenced by the available nitrogen in the soil or nitrogen supplied by fertilization, the varieties grown, and growing conditions including the seasons (nitrates being metabolized in the presence of light, crops grown in greenhouses and during the winter are typically loaded with nitrates). In cheeses and meats, nitrates are from additives used as preservatives [4]. The nitrates content for some vegetables (such as lettuce) can go up to 2000 mg. Therefore, the ADI of nitrates can be reached quickly depending on the quality of food and drinking water available [35].

Nitrates are not normally dangerous to human health. However, they can be reduced to nitrites which are toxic for humans, especially for infants who have immature digestive system that are more conducive to the reduction of nitrates to nitrites. Furthermore, the pH in the stomach of an infant being higher than that of an adult, this would favor an easier development of bacterial nitrate reductase activity [4]. Methemoglobinemia occurs when there is ingestion of a large amount of nitrates in conditions favoring their conversion to nitrites. It is due to a conversion of ferrous iron contained in hemoglobin to ferric iron, and can lead to severe anemia. Furthermore, nitrates are endocrine disruptors and as such form part of the molecules inducing goiter [36].

The analysis of fluorides showed concentrations of 6 mg/l, 8 mg/l, and 7 mg/l respectively for the samples from Rufisque, Castors, and Tilène. The daily dose recommended by WHO is 0.05 mg/kg or 3.5 mg for an adult of 70 kg. Our samples by themselves can provide up to a half (1.5 mg, 2 mg, 1.75 mg) of the daily fluorides intake recommended by WHO for the average Senegalese adult. Risks of fluorosis exist in the event of higher daily intake of about 0.1 mg/kg or 7 mg/day for the same adult. The possibility of such a high intake is very real considering other sources of fluorides such as drinking water [36]. Dental fluorosis appears after months or years of consumption of fluorides at levels higher than normal. Excessive consumption of fluorides at a rate of 200 μg/kg/day can cause skeletal fluorosis. However, fluorides are also important for dental health. They act on the mineralization of the tooth and have an antibacterial effect that protects against tooth decay.

The analysis results for chlorides revealed concentrations of 100 mg/l, 40 mg/l, and 120 mg/l respectively for the samples from Rufisque, Castors, and Tilène, with the samples from Castors having a significantly lower concentration than the other two. The recommended daily chlorides intake for an adult is in the order of 1 to 2 g. Daily consumption of watermelon from our studied samples would provide between 10 mg and 30 mg of chlorides, much lower than the recommended intake. Chlorides deficiencies are rare because they are contained in many foods thus ensuring adequate intake. Still, repeated vomiting and diarrhea can cause loss of chlorides resulting in muscle

cramps and fatigue. Excess chloride is harmful to human health because it can lead to the destruction of vitamin E and of the intestinal flora. Chlorine is irritating to the respiratory system.
The sodium concentrations obtained were respectively 27 mg/l, 26 mg/l, and 26 mg/l, which are roughly similar for the samples from all three localities. Therefore, the daily consumption of watermelon from our studied samples for an average adult would provide between 6.5 mg and 6.75 mg of sodium, much lower than the recommended daily intake of 1 to 2 g. A sodium deficiency can occur in case of diarrhea, vomiting, excessive sweating, acute renal failure, chronic nephritis, etc. This is often manifested in the form of an excessive hydration of the cells, in parallel to a dehydration of extracellular fluids. Excess sodium has important implications on the cardiovascular system and may cause hypertension, and heart or kidney failures.
Our results showed that consumption of the sample watermelons bought from Rufisque, Castors, and Tilène would provide sodium and chlorides ions well below the recommended daily intakes. On the other hand, although the calculated consumption of nitrates is equal to a quarter of the acceptable daily intakes, there is still a risk of toxicity since nitrates are present in a significant variety of foods. Finally, the amount of fluorides from the sample watermelons is relatively high compared to the recommended levels.

CONCLUSION

The use of specific electrodes for the determination of nitrates, fluorides, and chlorides, and of flame photometry for the determination of sodium ions, allowed us to assess the quality of watermelons sold in three separate markets in the region of Dakar (Rufisque, Castors, and Tilène). Our results strongly suggest setting up effective means of monitoring certain mineral elements in food and the environment in Senegal. Because of watermelon's accessibility in Senegal and its many therapeutic properties, trials should be carried out with regards to its use as a dietary supplement.

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