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Nitrate contamination of different organic and non-organic vegetable varieties: A case study in Morocco

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Abstract

Nitrates are chemical substances naturally present in the environment (plants, soil, water) and are involved in the natural nitrogen cycle. They represent the most stable oxidation state and are essential nutrients for plant growth. The exposure and ingestion of nitrates by the population are mainly through the consumption of vegetables and occasionally through water intake. The objective of this study is to determine the nitrate content of various varieties of vegetables from industrial agriculture consumed by the population in three cities in northern Morocco's Rabat-Salé-Kenitra region, as well as to demonstrate the health risk of consuming a high concentration of nitrate. The results determine the nitrate content of 77 vegetable samples harvested in Morocco's Rabat-Salé-Kenitra region. The results showed that nitrate concentrations in vegetables varied depending on different areas in the city and whether the sample was organic or non-organic. The results of our study vary from 31.4 mg/kg (red onion) to 7860 mg/kg (beetroot) in the different vegetable varieties studied. It is recommended that this level be monitored on a regular basis and that the population be made aware of the recommended daily consumption of nitrates (0.84 mg-N/kg/d or 3.7 mg NO3-/kg/d) in the region to prevent excessive exposure to these potentially toxic compounds. In addition, it is advised to promote sustainable agriculture techniques aimed at lowering overall nitrate levels in the food supply and boosting the health and sustainability of the area's food system.

Keywords: Health risks, Methemoglobinemia, Morocco, Nitrate, Non-organic vegetable, Organic vegetable, Vegetables.
Abbreviations: NO_3^-–Nitrates, NH_4^+_ Ammonium, NOAEL_No Observed Adverse Effect Level, mg-N/kg/d_ Milligram of Nitrogen per Kilogram per Day, WHO_ World Health Organisation, ADI_Acceptable Daily Intake, mg/kg_ Milligram per Kilogram, mg NO_3^-/kg/d_ Milligram of Nitrates per Kilogram per Day, MAFF_ United Kingdom Ministry of Agriculture, Fisheries and Food, mg/kg/day_ Milligram per Kilogram per Day, Fe_2^+_Ferrous Iron, Fe_3^+_Ferric Iron, ml_ millilitre, °C_Degrees Celsius, ppm_ Parts Per Million, NO_3-N_ Nitrate Nitrogen.

Introduction

Adequate fertilisation is favourable for modern agriculture in order to achieve high yields and optimal crop quality (Alexander et al., 2016). In fact, mineral nitrogen, which is essential for the production of the organic matter that constitutes living tissue, is mainly absorbed and assimilated by these organisms in the form of nitrate ions (Rasn and Rauj, 2018). Nitrates (NO_3^-) are stable ions and essential nutrients for plant growth. They are naturally present in the environment (plants, soil, water) and are part of the natural nitrogen cycle (fixation, assimilation, ammonification, nitrification, and denitrification), which ensures a balance between atmospheric, organic, and mineral nitrogen (mainly in nitrate form) (Brkić et al., 2017). Therefore, the use of nitrates is of great importance for agriculture, as they are one of the key nutrients present in fertilisers or ensuing from the decomposition of fertilisers in the soil, whether they are of animal (manure), plant (green manure) or chemical industry origin (Santamaria, 2006).

The influence of humans (development of agriculture and industry, increased population growth, economic and technological explosion) has considerably disrupted this natural cycle. Indeed, the excessive nitrogen (mineral or organic) contribution by industrial, domestic, or agricultural (fertilisers, crop residues, manure, use of nitrogenous fertilisers) activities leads to contamination of plants (vegetables, plants) and pollution of the groundwater by nitrates and nitrites (Alexander et al., 2016; El Baroudi et al., 2021).

Due to its high solubility, nitrate is excessively washed into the soil. In fact, nitrification occurs rapidly in well-aerated soils, therefore ammonium (NH_4^+) concentrations are low and NO_3^- is the main source of nitrogen, however, nitrification is inhibited in waterlogged or acidic soils, thus NH_4^+ accumulates (Crawford and Forde, 2002).

The presence of nitrates in excessive quantities in vegetables and water is considered potentially toxic for humans (Bian et al., 2020), whose daily consumption standard is limited by the World Health Organisation to 0.84 mg-N/kg/d (3.7 mg NO_3^-/kg/d) (FAO/WHO, 1995). It is based on a no-observed-adverse-effect level (NOAEL) of 83.5 mg-N/kg/d (370 mg NO_3^-/kg/d), measured in a chronic toxicity study in rats, to which an uncertainty factor of 100 has been applied. This acceptable daily intake (ADI) does not apply to infants under three months of age (WHO, 1998). The presence of nitrates in excessive quantities may be of agricultural (fertilisers), urban (inadequate sewage systems) or industrial origin.

Most vegetables can accumulate large amounts of nitrate. This concentration of NO_3^- in vegetables depends on biological and environmental/agricultural factors, growth and storage conditions (biological properties of the plant, soil type, amount of nitrate available in the soil, maturity of the plant, storage time) (Shokrzadeh et al., 2007; Dezhangah et al., 2022).

The Brassicaceae, Chenopodiaceae and Amaranthaceae families are known as the vegetables with the highest nitrate concentrations. Similarly, Asteraceae and Apiaceae families include species with high nitrate content (Santamaria, 2006). The population's exposure to nitrate is mainly through vegetables and occasionally through drinking water. Indeed, 80% of daily nitrate intake comes from vegetable consumption, and only 20% from water consumption (Ali et al., 2021). The determination of nitrate ion levels in vegetables is therefore of major importance in food safety assessments.

The toxicity of ingested nitrate is mainly related to its conversion to nitrite in the body. Indeed, consumption of nitrate/nitrite rich foods has been linked to the development of methemoglobinemia (Knobeloch et al., 2000; WHO, 2017; Rasn and Rauj, 2018), cancer (Keszei et al., 2013; Della Valle et al., 2013; Brkić et al., 2017) and diabetes (Parslow et al. 1997; Moltchanova et al., 2004; Srour et al., 2023).

Few studies have been conducted on the effect of mineral element accumulation during vegetable cultivation in Morocco. The objective of this study is to determine the nitrate levels in different varieties of vegetables consumed by the population of the Rabat-Salé-Kenitra region in Morocco and to demonstrate the health risk of regular consumption of high nitrate concentration.

Results

Nitrate levels in different vegetable varieties collected in the city of Salé

The nitrate levels in the different vegetable varieties collected in the city of Salé vary between 120 mg/kg (courgette) and 5092 mg/kg (Okra) with an average concentration of 1364.78 mg/kg. The nitrate levels for each vegetable are presented in detail in Table 1.

Nitrate levels in different vegetable varieties collected in the city of Kenitra

The nitrate levels in the different vegetable varieties collected in the city of Kenitra vary between 206 mg/kg (Green pepper) and 3724 mg/kg (Quince) with an average concentration of 1357.73 mg/kg. The nitrate levels for each vegetable are presented in detail in Table 2.

Nitrate levels in different vegetable varieties collected in the city of Rabat

The nitrate levels in the different vegetable varieties collected in the city of Rabat vary between 31.4 mg/kg (Red onion) and 7860 mg/kg (Beetroot) with an average concentration of 1623.12 mg/kg. The nitrate levels for each vegetable are presented in detail in Table 3.

Nitrate levels in organic vegetable varieties collected

The nitrate levels in the different organic vegetable varieties collected vary between 98 mg/kg (Red onion) and 6348 mg/kg (Beetroot) with an average concentration of 1199.75 mg/kg. The nitrate levels for each vegetable are presented in detail in Table 4.

Comparison of nitrate content between different vegetable groups

The highest nitrate levels were observed in root vegetables (beetroot with 7860 mg/kg), fruit vegetables (okra with 5092 mg/kg), leaf vegetables (spinach with 4930 mg/kg), tuber vegetables (white potato with 2580 mg/kg), bulb vegetables (garlic with 1578 mg/kg) and flower vegetables (cauliflower with 1316 mg/kg), respectively. Low nitrate concentrations were observed in bulb vegetables (red onion with 31.4 mg/kg), fruit vegetables (courgette with 120 mg/kg), leaf vegetables (lettuce with 141.6 mg/kg), root vegetables (carrot with 225.3 mg/kg), tuber vegetables (white potato with 233.8 mg/kg) and flower vegetables (broccoli with 714.6 mg/kg), respectively (Fig. 1).

Comparison of nitrate content between different organic and non-organic vegetables

According to the results of this study, some varieties of organic vegetables collected had higher nitrate concentrations than those observed in non-organic vegetables, namely, organic green pepper with 965.6 mg/kg and 1147 mg/kg against 206 and 208.5 mg/kg in the city of Kenitra and Salé respectively. Organic chilli pepper with 2013 mg/kg against 1284 mg/kg for non-organic chilli pepper collected in the city of Salé. organic tomato from market 2 with 441.2 mg/kg against 312, 246, and 357.3 mg/kg for non-organic tomatoes collected in the cities of Rabat, Kenitra, and Salé respectively, organic tomato from market 1 (194 mg/kg) presented, however, a concentration of nitrate inferior to that observed in non-organic tomato collected in the 3 cities mentioned. Organic red onion with 98 and 483 mg/kg against 31.4 mg/kg for non-organic red onion collected in the city of Rabat, the sample collected in the city of Salé (206.1 mg/kg) presented a higher nitrate concentration than that observed in organic red onion from market 2. Organic aubergine with 1544 and 2025 mg/kg against 1251 and 924 mg/kg for non-organic aubergine collected in the cities of Rabat and Kenitra respectively, the sample collected in the city of Salé (1605.8 mg/kg) had a higher nitrate concentration than that observed in organic aubergine from market 2 (1544 mg/kg).

Other varieties of organic vegetables collected had lower nitrate concentrations than those observed in non-organic vegetables, notably, organic green onion with 241.2 mg/kg against 1219.4 mg/kg for non-organic green onion collected in the city of Rabat. Organic quince with 1152 mg/kg against 3724 mg/kg for non-organic quince collected in the city of Kenitra. Organic white potato with 233.8 mg/kg against 2580 and 596 mg/kg in non-organic white potato collected in the cities of Kenitra and Salé respectively. Organic sweet potato with 736 mg/kg against 1632 mg/kg for non-organic sweet potato collected in the city of Salé. Organic turnip with 374.4 mg/kg against 767 and 706 mg/kg for non-organic turnip collected in the cities of Rabat and Salé respectively. Organic beetroot with 6348 mg/kg against 7860 mg/kg for non-organic beetroot collected in the city of Rabat, however, the sample of non-organic beetroot collected in the city of Salé had a lower concentration (4608 mg/kg) than those observed in organic beetroot.

Discussion

The results show a significant variation in the nitrate concentration of some samples of the same vegetable variety according to the city of sampling, namely, courgette [120 mg/kg - 1869 mg/kg], carrot [225. 3 mg/kg - 1582 mg/kg], red onion [31.4 mg/kg - 206.1 mg/kg], white potato [596 mg/kg - 2580 mg/kg], aubergine [924 mg/kg - 1605.8 mg/kg], beetroot [4608 mg/kg - 7860 mg/kg], okra [2436 mg/kg - 5092 mg/kg] and green cabbage [521 mg/kg - 1374 mg/kg]. However, other vegetable varieties showed more or less the same concentration in the different sampling cities: tomato [246 mg/kg - 357.3 mg/kg], green pepper [206 mg/kg - 208.5 mg/kg], red pepper [1141 mg/kg - 1843.2 mg/kg], turnip [706 mg/kg - 767 mg/kg] and red potato [409 mg/kg - 655 mg/kg]. Several parameters can explain this variation, indeed, the concentration of NO_3^- in vegetables depends on the biological properties of the plant, light intensity, soil type, temperature, humidity, plant density, plant maturity, growing season, harvesting time, the size of the plant unit, storage time and nitrogen source (Tamme et al., 2006; Rasn and Rauj, 2018). A study conducted on nitrate and nitrite levels in organic vegetables showed that spinach, cabbage, and aubergine had lower nitrate content in the samples harvested in summer, demonstrating the influence of climatic conditions on nitrate levels in a plant (Matallana González et al., 2010). The factors influencing nitrate concentration in vegetables are, therefore: biological, environmental/agricultural and growing and storage conditions (Shokrzadeh et al., 2007; Dezhangah et al., 2022). The amount of nitrate available in the soil (depending on the content of artificial fertiliser) seems to be a determining factor for the nitrate content of vegetables (Shokrzadeh et al., 2007). These same parameters may also explain the higher concentrations of some of the organic vegetables compared to the non-organic vegetables, notably, tomatoes collected in the organic market 2 had a concentration of 441.2 mg/kg compared to a concentration of [246 mg/kg - 357.3 mg/kg] for non-organic tomatoes, organic red onion [98 mg/kg - 483 mg/kg] and non-organic red onion [31.4 mg/kg - 206.1 mg/kg], organic green pepper [965.6 mg/kg - 1147 mg/kg] and non-organic green pepper [206 mg/kg - 208.5 mg/kg], organic chilli pepper 2013 mg/kg and non-organic chilli pepper 1284 mg/kg, organic aubergine [1544 mg/kg - 2025 mg/kg] and non-organic aubergine [924 mg/kg - 1605.8 mg/kg]. Other varieties of organic vegetables had lower nitrate concentrations than the non-organic vegetables: organic white potato 233.8 mg/kg and non-organic white potato [596 mg/kg - 2580 mg/kg], organic turnip 374.4 mg/kg and non-organic turnip [706 mg/kg - 767 mg/kg], organic sweet potato 736 mg/kg and non-organic sweet potato 1632 mg/kg, organic quince 1152 mg/kg and non-organic quince 3724 mg/kg, organic green onion 241.2 mg/kg and non-organic green onion 1219.4 mg/kg. This can be explained, in addition to the above-mentioned parameters, by the absence of the use of pesticides and nitrogenous fertilisers as well as the low concentration of nitrate available in the soil due to the absence or low content of artificial fertiliser.

The variation in nitrate content between different samples of the same vegetable has also been reported in a study by Prasad and Chetty (2008). Other studies have also shown that the nitrate concentration of vegetables can vary greatly between different countries and regions (Tamme et al., 2006; Reinik et al., 2009; Bahadoran et al., 2016; Brkić et al., 2017).

In this study, root vegetables had the highest nitrate levels compared to the other vegetable groups studied. However, the lowest nitrate levels were observed in bulb vegetables. A study by Salehzadeh et al. (2020) on vegetables grown in the city of Sanandaj showed that the highest nitrate levels were found in leaf vegetables, followed by root vegetables and fruit vegetables. Matallana González et al. (2010) also showed that nitrate levels were much higher in leaf vegetables than in flower or fruit vegetables. A survey conducted by the UK Ministry of Agriculture, Fisheries and Food (MAFF) revealed that nitrate concentrations above 1000 mg/kg were found in lettuce, spinach, celery and beetroot, while potatoes, cabbage, and spring green vegetables had concentrations ranging from 100 mg/kg to 1000 mg/kg, whereas tomatoes had the lowest concentrations (below 100 mg/kg) (MAFF, 1992). Another study conducted by Abo Bakr et al. (1986) on some vegetables consumed by the Egyptian population revealed that the highest levels of nitrate were observed in leaf vegetables with the highest value recorded in spinach. Similarly, a study conducted by Tamme et al. (2006) revealed that the highest average nitrate levels were detected in dill, spinach, lettuce and beetroot, while tomato, onion and potato contained the lowest level of nitrate.

Taking into consideration only the consumption of vegetables, an adult weighing 70 kg would need to consume not less than 8.25 kg of red onion (31.4 mg/kg) per day, while 33 g of beetroot (7860mg/kg) per day would be sufficient to exceed the ADI for nitrates. The results show the need to control the daily consumption of vegetables despite their recognised benefits, in accordance with the consumption of other foods and water, to ensure compliance with the daily nitrate consumption standard limited according to the World Health Organisation to 3.7 mg/kg/day, which represents 259 mg per day for a 70 kg adult, taking into consideration that this ADI does not apply to infants under three months of age, in order to avoid the potential toxicity of nitrates on human health. This control is also necessary to limit the formation of nitrites, which can also come from other sources, such as drinking water. A study on nitrite levels in well water in different rural areas in Morocco showed the presence of NO_2^- in this water consumed by the population living in the area (El Baroudi et al., 2021).

Several studies have reported beneficial effects and therapeutic properties of nitrates in relation to cardiovascular disease (Bryan et al., 2007; Kevil et al., 2011; Machha and Schechter, 2011), diabetes (Ghasemi and Zahediasl, 2013), hypertension, blood pressure regulation and vasodilation, inhibition of inflammatory endothelial cell recruitment and platelet aggregation (Rasn and Rauj, 2018; Webb et al., 2008), metabolic syndromes and insulin resistance (Ghasemi and Zahediasl, 2011; Lundberg et al., 2008). Similarly, a study by Jones (2014) shows that nitrate

Table 1. Nitrate levels in mg/kg in different vegetable varieties collected in the city of Salé.

Vegetables	Nitrates in mg/kg	Vegetable groups
Red onion	206.1	Bulb
White onion	363.6	Bulb
Leek	562	Bulb
Garlic	1578	Bulb
Fennel	1020	Bulb
Chives	952	Bulb
Cauliflower	1316	Flower
Broccoli	714.6	Flower
Courgette	120	Fruit
Tomato	357.3	Fruit
Green pepper	208.5	Fruit
Red pepper	1843.2	Fruit
Cucumber	421.5	Fruit
Armenian cucumber	206	Fruit
Aubergine	1605.8	Fruit
Long calabash	838	Fruit
Red cherry tomato	810	Fruit
Orange cherry tomato	275	Fruit
Green bean	843	Fruit
Okra	5092	Fruit
Pumpkin	1984	Fruit
Butternut squash	179	Fruit
Musquee de provence pumpkin	876	Fruit
Chilli pepper	1284	Fruit
Peas	3648	Fruit
Lettuce	141.6	Leaf
Spinach	4930	Leaf
Red cabbage	1320	Leaf
Green cabbage	1374	Leaf
Basil	1716	Leaf
Purslane	3075	Leaf
Carrot	225.3	Root
Beetroot	4608	Root
Turnip	706	Root
Round turnip	2272	Root
Radish	692	Root
Celery	3112	Root
Ginger	888	Root
White potato	596	Tuber
Sweet potato	1632	Tuber

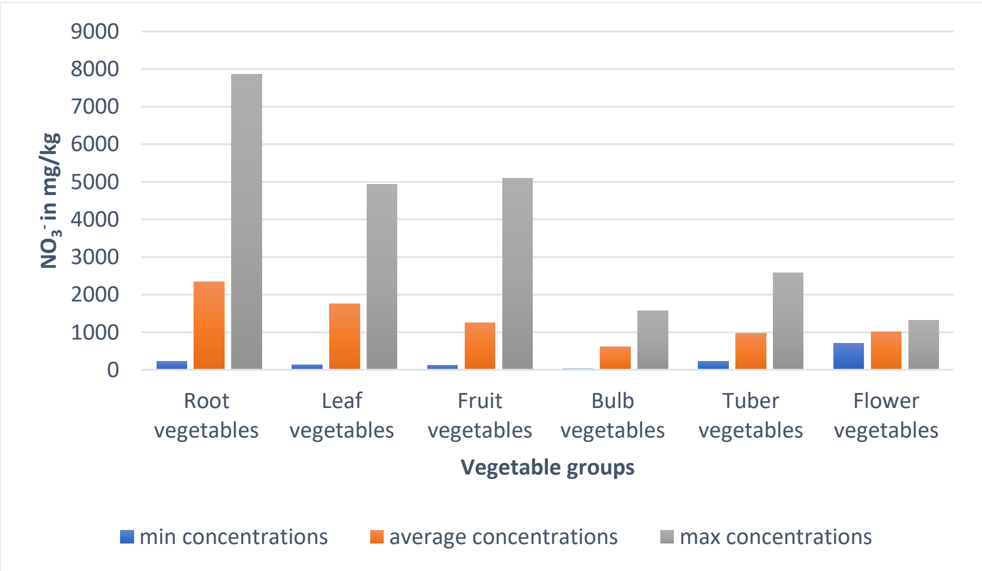

Fig. 1. Minimum - average - maximum nitrate content in the different vegetable groups in mg/kg.

Table 2. Nitrate levels in mg/kg in different vegetable varieties collected in the city of Kenitra.

Vegetables	Nitrates in mg/kg	Vegetable groups
Courgette	1218	Fruit
Tomato	246	Fruit
Green pepper	206	Fruit
Red pepper	1141	Fruit
Aubergine	924	Fruit
Okra	2436	Fruit
Quince	3724	Fruit
Brussels sprouts	986	Leaf
Carrot	1065	Root
White potato	2580	Tuber
Red potato	409	Tuber

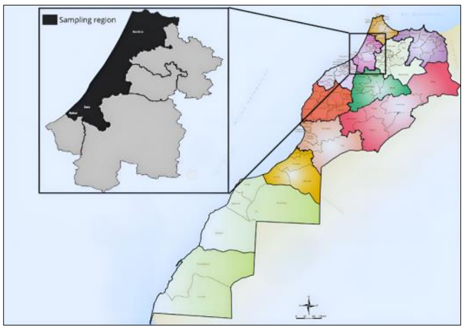

Fig. 2. sampling region map

Table 3. Nitrate levels in mg/kg in different vegetable varieties collected in the city of Rabat.

Vegetables	Nitrates in mg/kg	Vegetable groups
Red onion	31.4	Bulb
Green onion	1219.4	Bulb
Courgette	1869	Fruit
Tomato	312	Fruit
Red pepper	1786.5	Fruit
Aubergine	1251	Fruit
Green cabbage	521	Leaf
Carrot	1582	Root
Beetroot	7860	Root
Turnip	767	Root
Red potato	655	Tuber

Table 4. Nitrate levels in mg/kg in different organic vegetable varieties collected.

Vegetables	Nitrates in mg/kg		Vegetable groups
Red onion	483 (1)	98 (2)	Bulb
Green onion	241.2 (2)		Bulb
Tomato	194 (1)	441.2 (2)	Fruit
Green pepper	965.6 (1)	1147 (2)	Fruit
Chilli pepper	2013 (1)		Fruit
Aubergine	2025 (1)	1544 (2)	Fruit
Quince	1152 (1)		Fruit
Beetroot	6348 (2)		Root
Turnip	374.4 (2)		Root
White potato	233.8 (1)		Tuber
Sweet potato	736 (2)		Tuber

(1) : Vegetable from Market 1

(2) : Vegetable from Market 2

consumption, mainly in the form of beetroot juice, can result in improved performance, exercise capacity, muscle output and energy production. In low concentrations, nitrates are not toxic in themselves. However, their presence in excessive quantities in vegetables, water and food, in general, is considered potentially toxic to humans. The toxicity of nitrates is due to their transformation into nitrites and nitroso compounds, in particular nitrosamines and nitrosamides (Brkić et al., 2017; Karwowska and Kononiuk, 2020). It is mainly related to the occurrence of methemoglobinemia, which results from the binding of the nitrites formed on haemoglobin and the oxidation of ferrous iron (Fe_2^+) to ferric iron (Fe_3^+), transforming haemoglobin into methaemoglobin, which impairs the transfer of oxygen to the body's tissues (Knobeloch et al., 2000; Mensinga et al., 2003; Taylor et al., 2021). The risk is higher in babies and infants because the pH in the stomach tends to be higher than that of an adult, allowing for an easier proliferation of bacteria with nitrate reductase activity, which is favourable to the conversion of ingested nitrates (in high concentrations) into nitrites. As a result, the child develops a blue colouration of the skin. This pathology, more frequent in infants, is also called blue baby syndrome (Knobeloch et al., 2000; Rasn and Rauj, 2018; Karwowska and Kononiuk, 2020). It has also been reported that nitrate toxicity may be linked to the development of other diseases, including cancer (Keszei et al., 2013; Della Valle et al., 2013; Brkić et al., 2017), diabetes (Parslow et al., 1997; Moltchanova et al., 2004; Srour et al., 2023) and Alzheimer's disease (Rasn and Rauj, 2018).

Materials and methods

Vegetables materials

A total of 77 vegetable samples were collected during the period from June 2021 to October 2021 in the region of Rabat-Salé-Kenitra in Morocco. The organic samples were collected from 2 different organic markets in the city of Rabat (Fig.2).

Preparation of vegetable extracts

The extracts are prepared by weighing 40 grams of each vegetable variety and adding 300 ml of distilled water. After grinding and filtering the residues, the extracts are collected in Pyrex glass flasks and placed in a water bath at 100°C for 20 minutes and then kept at ambient temperature for 10 minutes before assay.

Definition of nitrate

Nitrate is an inorganic compound composed of one nitrogen (N) and three oxygen (O) atoms and occurs naturally in the environment (Marhamati et al., 2021). It is the most stable element in the nitrogen cycle and is the product of the aerobic stabilisation of organic nitrogen (Masime et al., 2013). Nitrates occur naturally in soils containing nitrogen-fixing bacteria, decaying plants, septic system effluents and animal manure. Other sources of nitrates include nitrogen fertilisers and airborne nitrogen compounds emitted by industry and automobiles (Manassaram et al., 2006). Sources of nitrate pollution include fertiliser use, animal waste, municipal and industrial waste and lightning (Masime et al., 2013). Nitrate is an essential mineral nutrient for plant growth. For this reason, nitrate salts such as potassium nitrate (KNO_3), sodium nitrate ($NaNO_3$), calcium nitrate ($Ca(NO_3)_2$) or ammonium nitrate (NH_4NO_3), are used for the manufacture of nitrogenous fertilizers. Nitrate is also used in the composition of explosives or special cement types, as a food additive and colouring agent, for the coagulation of latex, in the nuclear industry and for odour and corrosion control in hydraulic systems (IARC, 2010).

The main source of nitrates absorbed by the body is food, with vegetables being the main source of these compounds in the diet (Ma et al., 2018). It is also found in some foods as additives (Parvizishad et al., 2017).

Determination of nitrate levels

Nitrate (NO_3^-) levels in vegetable samples are determined using the HI97728 photometer, which measures NO_3^- in samples up to 30 mg/l (ppm) NO_3-N, or 132.9 mg/l NO_3^-. This technique is based on the cadmium reduction method (HANNA Instruments).

Statistical analysis

The comparison of nitrate concentrations in collected vegetables according to the cities of collection was done by comparing the concentrations of the same vegetable variety, the variety collected in only one of the cities and absent from the other cities was excluded from this comparison. The calculation of the average concentration for each city was done by taking into consideration all the vegetables collected in each city. For the comparison by vegetable group, the minimum and maximum concentration of each vegetable group was calculated. The calculation of the average concentration for each vegetable group was carried out by taking into consideration all varieties that belong to the vegetable group concerned. For the comparison of nitrate concentrations according to the organic or non-organic nature of the collected vegetables, only the non-organic vegetable varieties that were also present in the collected organic vegetable varieties were included in this comparison. All non-organic vegetable varieties collected in this study, but not collected during the collection of the organic vegetables, were excluded from this comparison. The calculations (minimum, maximum, and average) and the graphical representation were made with SPSS V25 and Excel 2019.

Conclusion

In this study, the results revealed a variation in the concentration of nitrates in vegetables depending on the city and whether the sample was organic or non-organic. The highest nitrate levels were observed in root vegetables (beetroot). While the lowest nitrate levels were observed in bulb vegetables (red onion). These results reveal the nitrate content in vegetables consumed by the population of the Rabat-Salé-Kenitra region in Morocco, and allow the control of the daily consumption of nitrates in the region in accordance with the ADI, in order to avoid the potential toxicity of the latter on the health of the population, especially in the prevention of the appearance of methemoglobinemia. Limiting the excess of this anion in soils and plants has therefore become one of the major challenges for agriculture today.

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